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NEW ENGINEERING & DEVELOPMENT INITIATIVES --
POLICY AND TECHNOLOGY CHOICES

Consensus Views
of
User/Aviation Industry Representatives

Coordinated by
Economics & Science Planning, Inc.

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For
U.S. DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration

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16. Abstract

This report summarizes an evaluation by the users of the National Airspace System (NAS) of those policy and technological issues critical to FAA Engineering and Development (E&D) initiatives.

Five topic groups were organized to evaluate the critical issues that must eventually structure a program of E&D initiatives, as follows:

(1) Productivity and Automation,
(2) Airport Capacity,
(3) Freedom of Airspace,
(4) Safety and Flight Control,
(5) Non- and Low-Capital Policies to Improve Efficiency.

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POLICY AND TECHNOLOGY CHOICES

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NEW ENGINEERING & DEVELOPMENT INITIATIVES -- POLICY AND TECHNOLOGY CHOICES

INTRODUCTION AND SUMMARY

Final Report
March 1, 1979

NEW E&D INITIATIVES -- POLICY & TECHNOLOGY CHOICES

Introduction and Summary

This report summarizes an evaluation by the users of the National Airspace System (NAS) of those policy and technological issues critical to FAA Engineering and Development (E&D) Initiatives. Approximately 260 experts of the aviation community, representing 60 organizations, organized into five topic groups, held 60 meetings over a seven month period. All major sectors of the aviation community were represented: airline pilots, trunk and commuter airline operators, the owners and pilots of the entire spectrum of general aviation aircraft, air traffic controllers, airport operators, helicopter owners and operators, aircraft and equipment manufacturers.

Many FAA, NASA, DOD, MITRE and Lincoln Laboratory experts, as well as many professionals in the aviation community, provided essential briefing material and special studies. The cooperation of the entire aviation community was exceptional. No doubt this was in part induced by FAA's interest and support of this process. The users are hoping for a positive response from FAA to their suggestions.

Five topic groups were organized to evaluate the critical issues that must eventually structure a program of E&D Initiatives, as follows:

(1) Productivity and Automation - Mr. Robert Everett, Chairman
(2) Airport Capacity - Mr. Joseph Blatt, Chairman
(3) Freedom of Airspace - Mr. Gilbert Quinby, Chairman
(4) Safety and Flight Control - Dr. Roger Phaneuf, Chairman

(5) Non- and Low-Capital Policies to Improve Efficiency - Dr. George Douglas, Chairman

The entire process was coordinated by Dr. Lawrence Goldmuntz.[1/] The biographies of these chairmen are attached as Appendix A.

Work statements were provided to the topic groups and were generally accepted. The work statements appear as Appendix B.

The results of the Topic Groups' efforts, Chapters I through V, are the substance of this report. These chapters have been reviewed by users and their comments have been incorporated in the text to the extent that they achieved unanimity. This introduction and summary integrates users recommendations and generalizes some of their observations. User comments on this introduction and summary were solicited and received and were taken into account in the preparation of this final document to the extent they were consistent with the consensus achieved in the topic groups. However, this summary has been approved only by the coordinator and topic group chairmen and represents their understanding of the users' consensus achieved. The users do not necessarily agree with the Appendices included in Volume II as supporting documents for Chapters I through V, but considered them helpful in their deliberations.

The requirements for E&D initiatives were reviewed in the context of the procedures and institutional policies in which the E&D products will be embedded. Thus the users addressed certain procedures and policies when appropriate, as well as the E&D products themselves.

The rapid growth in aviation and the substantial forecasted growth over the next two decades -- if unconstrained -- impinged heavily on the users' deliberations. FAA forecasts are summarized in Table 1.

[1/] President of Economics & Science Planning, Inc. which is under contract DOT-FA77WA-4001 with the FAA.

Table 1

Indices of Aviation Growth

	1978 (actual)	1990 (forecast)	2000 (forecast)
Number of Aircraft ((000) omitted)			
General Aviation	187	311	390
Helicopter	4.7	8	12
Air Transport	2.5	3	3.4
IFR Aircraft handled by centers ((000,000) omitted)	28.1	45.6	60.1
Terminal Operations with control service ((000,000) omitted)	66.7	100	122

The air traffic control system must have the capacity to handle the enormous predicted rates of growth of general aviation (60%) and helicopters (70%) in the next decade and the additional substantial growth thereafter. Moreover, the number of Instrument Flight Rules (IFR) aircraft handled and the number of terminal operations with control service forecast for 1990 and 2000 do not include the increases in these categories due to recent FAA proposals. Therefore users realized that the control process must become more effective if it is to handle this additional traffic without constraining aviation.

While some special studies were accomplished to help the topic groups form their judgments, it was not possible, in view of the short duration of the initiatives process, to undertake any studies in great depth. To a certain extent, the generality of some of the recommendations is due to the lack of these studies. In some areas FAA has a great deal of data and has made excellent analyses of various technological alternatives. However in some other cases, adequate data is not available and available analyses do not seem complete. For example, it is not

certain how many aircraft hours are flown IFR without a transponder, what is the average blip scan ratio for those aircraft that are tracked by primary radar, what is an acceptable "stabilized" approach path for an aircraft flying a Microwave Landing System (MLS) curved approach, what would be the alarm rate for the Discrete Address Beacon/Automatic Traffic Advisory and Resolution Service (DABS/ATARS) in the terminal environment, what are the capacity/noise relationships under the new noise regulations at key hub airports, etc? The combined judgment and experience of the user community was frequently helpful in bridging some gaps.

The users did not invent any major new approaches to air traffic control. This could have been expected, since many skilled individuals in FAA, NASA, MITRE, Lincoln, the manufacturers and user organizations have devoted their entire careers to solving air traffic control problems, and one might expect that what could be invented to meet a requirement has already been conceived.

Users evaluated some new concepts, for example: The Air Traffic Control Radar Beacon System (ATCRBS) based Instrument Landing Aid (ILA) was not reviewed favorably since its implementation would require some aircraft to carry three systems, ILA, ILS and MLS. However, a continuing search for low-cost landing aids was endorsed. The NAVSTAR satellite navigation system, while promising to helicopter and some other users who expressed a need for low altitude, as well as remote area navigation and air traffic control, was not viewed by many users as necessary to satisfy a pressing requirement. The user community supported the application of new technologies in computer hardware and architecture, data links and displays to Air Traffic Control (ATC) problems, since these technologies may make possible beneficial approaches to ATC that could not have been achieved previously.

In summary, the user community has criticized few of the ongoing FAA E&D programs, has suggested some new E&D programs that FAA *wasn't already* considering, has provided some important policy guidelines and has urged acceleration of many ongoing efforts. The implications on resources, both money and manpower, of these suggestions deserve serious consideration by FAA management. The users know they fund E&D products through the trust fund and were not reckless with their suggestions.

A major contribution of the user community in this consultative process was to achieve a substantial degree of consensus on the major thrusts of future E&D programs. Considering the diverse and frequently competing interests of the various components of the user community, this is a remarkable achievement. Certain key elements of the consensus achieved by the user community are listed here. The detailed recommendations are presented in Chapters I through V.

1. ATC clearance generation should continue as a ground system function to achieve safe and efficient movement of air traffic; ATC clearance execution should continue to be an airborne function; automatic control of aircraft flight from the ground is not appropriate.

2. The role of primary radar in the en route system should be directed toward the detection and mapping of hazardous weather rather than aircraft tracking. Weather detection requires a pencil beam, high frequency, linear polarization, a low rotational rate and perhaps Doppler processing. Those characteristics are not optimum for aircraft tracking. At the current level of transponder equippage there is little requirement to track aircraft by primary radar but there is a need for better weather inputs to both the controller and the pilot. FAA should not purchase new or upgrade present en route radars for tracking aircraft, but should invest in radars designed for weather detection. This policy must not compromise the availability of non-

transponder procedural separation in those portions of the airspace where it is currently permitted, nor should the present radar system be discontinued until the new weather radar is commissioned.

It seems clear that the overall aircraft surveillance requirements of en route air traffic control can be better met, given fixed resources, by an all-beacon system augmented by a network of weather radars than by maintaining the present network of long-range aircraft surveillance radars. If this change is to be implemented, specific provisions must be made for handling IFR aircraft with transponder failure. It will also be necessary, at least for some transition period, to adapt the En Route Air Traffic Control system to occasional routine handling of non-transponder-equipped aircraft and to aircraft whose transponders lack Mode C altitude reporting.

3. The en route air traffic control process - by means of new computational techniques - no longer has to depend on increased sectorization of the airspace to handle increased traffic. The future system should manage adjoining airspaces so that boundaries are transparent. The computerized generation of conflict-free clearances by an Automated En Route ATC (AERA) type system and their transmission by DABS data link to aircraft will expedite traffic by reducing the controller work-load induced restraints with respect to direct routings and desirable altitudes. If successfully developed and when fully implemented, it might improve controller productivity by a factor of two. The cockpit cues provided by voice "party line" communication, whether manual or automatic, must be maintained at least during the DABS transition period and perhaps thereafter. Together with DABS/ATARS the en route air traffic control process should be able to generate and transmit to cockpits weather and relevant traffic information so that the pilot can monitor clearances and in certain airspaces participate in the separation process and movement of traffic, should this prove to be desirable.

4. The replacement of a real-time complex computer-based system on which lives may depend, such as the en route 9020s or the Autoland Radar Terminal System (ARTS) II and III:

a. Should not include a large change over in a single step so as to avoid the potential for major software validation problems.

b. Should not stop additional functions from being added to the existing system while waiting for the replacement.

c. Should result in a system designed for continuing evolution.

The advent of distributed processing and the decreasing cost of computer hardware makes all this feasible with a high degree of reliability.

5. Terminal area automation objectives should be to provide aids to the controller's metering sequencing and spacing capability. The clearances provided must be conflict-free and accommodate wake vortex avoidance sensor inputs, as well as profile descents. This terminal control process should be capable of handling arrivals to independent parallels, staggered arrivals to dependent parallels and intersecting runways, as well as taking into account departures, missed approaches and holding. The terminal metering and spacing control process must be coordinated with en route metering and spacing and national flow control. The outputs of terminal automation should be capable of delivery to the cockpit in various formats: (1) radar vector clearances for transmission by the controller; (2) conflict-free clearances transmitted directly by data link; (3) merge sequences and spacing information for aircraft equipped with cockpit traffic displays; or (4) time schedules at waypoints for 4D RNAV equipped aircraft, assuming that the additional cockpit capabilities described prove advantageous.

6. Possibilities for increasing productivity and reducing costs by consolidating ATC facilities (e.g., center with center, terminal with center, etc.) should be investigated.

7. Pilot and controller confidence in automation is crucial for automation to benefit productivity. Therefore the primary air traffic control system must be designed with extraordinary reliability. The E&D program must deal with the identification and development of failure protection and backup capabilities which will provide substantial improvement in reliability as compared to today's system. This E&D program should include an effort which is independent of the automation design team and has the continuing mission of looking for and characterizing possible failure modes, i.e., trying to "break the system".

The backup reliability effort should include consideration of the following concepts:

a. The automation should be designed so that the air traffic controller who is supervising the traffic situation is able to provide backup ATC services to maintain safety even though these backup systems may not be as efficient as the first line of ATC. This backup system should include monitoring and planning aids on displays driven by hardware and software which is independent from the main automation system.

b. Automation should have the capability of providing the pilot with traffic and runway occupancy information should this prove desirable to improve system reliability and to expedite traffic.

c. ATARS should be the collision prevention backup for DABS-equipped aircraft within DABS ground station coverage. Active Beacon Collision Avoidance System (BCAS) should provide collision prevention backup outside of DABS ground station coverage, or in the event of a DABS ground station breakdown. Further development of BCAS is warranted to provide backup aircraft separation assurance for a full range of traffic environments. The performance of ATARS and BCAS under Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC) in terminal environments should be more fully evaluated to determine their interaction with current procedures. The transition from ATARS to BCAS for backup protection when leaving DABS ground station coverage and possible mutual reinforcement of the two systems within DABS ground station coverage should be more fully investigated.

d. Adjoining facilities should be equipped to provide backup control for each other. The ground system should be required to continuously compute and update a set of backup clearances to be either stored in the aircraft or ready for transmission via data link.

e. Simulated failure training exercises for air traffic controllers and pilots should be part of the process for maintaining proficiency in dealing with failures.

8. Human performance and interface with evolving ground and airborne equipment requires E&D beyond current FAA efforts so as to maintain safety levels while improving productivity. E&D should define the needs of a controller to manage an automated control process and to maintain pro-

ficiency and alertness. Pilot actions are cited more than any other factor in accidents for all aviation sectors. Nevertheless additional cockpit information may be valuable to achieve closer separations, expedited traffic and monitoring of automated clearances.

E&D on the Cockpit Display of Traffic Information (CDTI) should answer a number of vital questions, for example:

a. How many displayed targets, what type of target information is appropriate, and what target parameters are needed and what other information, such as weather or area navigation data should be integrated in the display?

b. When a pilot believes (based upon CDTI information) that separation standards are violated, what procedures should be followed? What is the overall effect on safety and on pilot and controller workload?

c. Does the use of a CDTI and a potential division of traffic separation responsibility result in safe separation in all situations including those where elements of the ground or airborne ATC systems have failed and where there is a mix of equipped and unequipped traffic?

E&D should address techniques for improving pilot training and maintenance of pilot proficiency, particularly with respect to flight simulation, for example:

a. What is the importance of motion to the training of various flying maneuvers and for the various skill levels applicable to each

segment of aviation? How can a minimum standard of simulator capability be established for the various levels of pilot training that achieves appropriate safety goals in the most cost-effective manner?

b. How can visual simulators be classified to relate the information content of the visual scene to the various training objectives? Included in this examination should be questions of simulated visual illusions, disorientations, distortion by precipitation and other real world visual problems.

9. While E&D can increase terminal capacity, it cannot replace the need for more runways and airports and for fuller use of existing airports such as Midway and Dulles, and the need for less reliance on transfers at key airports such as O'Hare and Atlanta, and for maintaining the current inventory of reliever and general aviation airports. Therefore technology and runway construction, as well as institutional approaches are needed to provide the forecasted need for capacity. However all sectors of the user community rejected pricing mechanisms for allocating scarce runway capacity. One continuing problem may be the reaction of communities bordering airports to increased activity.

10. The E&D recipe to increase runway capacity is well known, but its implementation is too slow. For example, terminal area Metering and Spacing (M&S) automation is a long delayed but essential ingredient in the search for capacity increases at major airports. Both closer lateral spacing between runways and closer longitudinal separations on approach under IMC can be safely achieved, approximating those obtained under VMC. For example, the improved guidance capability of MLS and the improved communication and surveillance capability of DABS operating at approxi-

mately a one second data rate should permit a runway separation of 2,500 feet. As another example, the delivery accuracy of terminal M&S in conjunction with wake vortex alleviation or avoidance, and achievable shorter runway occupancy times, should have a 2-nautical mile longitudinal approach spacing as a reasonable goal. However, it may be necessary to have information on nearby traffic and runway occupancy available to the cockpit, as well as the control process, to achieve this goal. Wake vortex alleviation seems sufficiently promising that FAA should examine the feasibility of requiring wake vortex alleviation systems on newly certified aircraft, as well as on the current wide body jets. Capacity limiting interference between airports can probably be minimized by MLS and RNAV; capacity limiting interference between runways on the same airport can probably be minimized by MLS-guided missed approaches. Dual glide slopes provided by MLS may be a useful technique to alleviate wake vortices during IMC. While there are E&D products that are generally useful to improve airport capacity, they may have to be tailored to site specific airport needs.

11. All sectors of the user community are concerned about the accuracy, availability, timeliness and cost of weather information. This concern persists in spite of FAA's Aviation Weather System Program Plan. Users raise the following issues:

a. Will the National Weather Service (NWS) weather radar network provide the coverage and the turbulance detection needed by aviation? The aviation community has recommended that FAA's en route primary radars be replaced with a network of radars oriented toward weather detection rather than target tracking. How can FAA's weather radar network supplement the NWS network and what will be the performance of the combined NWS/FAA radar network?

b. The intensity of turbulance and the level of precipitation are not well correlated and the improvement to be obtained with Doppler and precipitation gradients is uncertain. Priority E&D efforts are needed to resolve this issue.

c. FAA plans to handle Pilot Reports (PIREPS) in a more systematic manner than at present for transmission to controllers and through them to pilots. The aviation community recommends that PIREPS also be used in conjunction with the ground network to improve weather forecasts. E&D is needed to determine how best to integrate PIREPS with ground radar for forecasting, as well as for assisting pilots to avoid potentially dangerous weather. Furthermore, E&D is needed to develop an improved automatic airborne weather sensing system both for general aviation and air carrier aircraft to measure weather phenomena and for transmission via DABS to the ground. This program should include analysis of how to select the aircraft sample and process the transmitted data.

d. FAA should develop an improved en route weather information service that would provide the timely dissemination of weather data obtained from PIREPS and the ground network in a manner that doesn't depend primarily on communications with an FSS or ATC facility which tend to be overloaded, but is available on regional broadcasts or by discrete access.

e. FAA should implement in the Automated Low-Cost Weather Observation System (ALWOS) program the automatic sensing of cloud height below 5,000 feet, visibility or visual range, wind direction and speed, temperature and altimeter setting. E&D

should be directed toward obtaining additional capabilities, such as measurement of dew point, precipitation, wind gusts, prevailing cloud height and obstructions to vision - if these can be accomplished cost effectively. To the general aviation community this development, along with a communications capability to disseminate the data in a timely fashion, is the most important E&D safety program. Weather is observed at less than half of the 1,700 airports having published Instrument Approach Procedures, and is frequently more than one hour old. This situation is a significant restraint on the safe and efficient use of the airspace.

f. The air crew should be provided with time critical hazardous weather information, such as wind shear on approach, with the same priority as conflict alert or minimum safe altitude warning. This requires the development of sensors and techniques to present hazardous weather to the control process, means for prompt delivery of weather data to cockpits so as to minimize workload and to provide assurance of the compatibility of ground-derived and air-derived warnings.

12. Electronic Flight Rules (EFR) are procedures that should be an objective of an E&D program. In regions where DABS coverage is available, EFR would permit a DABS equipped aircraft to fly in IMC where traffic densities are light without necessarily filing any, or a complete flight plan, since aircraft intent in this airspace may not be needed at all times to provide separation safely. There would be no limitation to the use of this same airspace in IMC by aircraft operating under IFR procedures with no additional equipment. EFR procedures in the DABS environment should be evaluated. Extensions of EFR to the current ATCRBS environment and to non-surveilled airspace using airborne collision avoidance systems or low-cost extensions to the DABS ground environment should also be investigated.

13. Users proposed E&D initiatives that could make airspace more readily available. For example:

a. Develop better visual and electronic marking of obstructions.

b. Explore means to reduce existing separation criteria by use of more accurate navigation equipment using existing navigation systems.

c. Determine the performance of current altimetry systems above flight level (FL) 290 and then develop, test and publish methods and techniques which would permit vertical separations less than the current 2,000 feet above FL 290.

d. Undertake an analysis to determine why RNAV is apparently underutilized in the ATC system.

e. Determine whether there is a better mix between preplanned published navigation procedures and radar vector navigation techniques than presently used.

f. Improve communications between and within Federal agencies and identification of responsibility to optimize the joint use of special use airspace.

14. Communications are essential to the ATC system and users proposed the publication of a national aviation communications plan that would include the funding, equipment, manpower and timetable necessary to upgrade the entire aviation voice and data communications network, air-to-ground and point-to-point with particular attention to techniques for reducing mutual

interfering VHF communications and for identifying VHF communication coverage deficiencies.

15. The user community did develop some general conclusions concerning operational restraints on E&D objectives. For example, all users recognize the need for evolutionary development of the ATC system - not as an excuse for slow development - but as a recognition of the limits to change in a system that operates in real time with many lives at stake and with massive investments in the training and proficiency of hundreds of thousands of people and measured in the tens of billions of dollars of equipment. This evolutionary requirement is certain to cause complications, expense and delays in upgrading center and terminal automation. It may also bar certain developments. For example, many airborne collision avoidance systems face the implementation dilemma. The user obtains protection only against similarly equipped users. Therefore there is little incentive to become equipped unless all became simultaneously equipped. Simultaneous equippage would require draconian measures by FAA which would be difficult to justify especially in the political arena, or it would require an infusion of relatively painless money, permitting - for example - the use of aviation trust funds for the equippage of private aircraft. This seems to be an unlikely possibility. The aviation community has not been able to identify the panacea for the implementation dilemma and therefore the users have accepted BCAS, which while more expensive than some other approaches can detect and avoid DABS equipped aircraft with high probability and ATCRBS equipped aircraft with some capability.

16. A constant concern of the user community relates to the length of time taken to complete and implement certain vital E&D programs. For example, M&S has been under development for a decade and still has many remaining uncertainties so that an eventual implementation date is simply not in sight.

The rate of development of the Vortex Avoidance System (VAS) is of equal concern. Meanwhile the airport capacity issue becomes ever more serious.

17. Blind reliance on arbitrary goals or safety standards untutored by data or validated models is likely to be counterproductive. For example, the goal for automatic systems is ten million landings per accident. The reliability standard for autoland subsystems was derived from this goal to be one failure in a billion landings. During the period 1964-1975, approximately 11,000 landings per accident were achieved under CAT-I conditions while making manual precision approaches. If all necessary requirements for use were satisfied, an automatic system capable of one million landings per accident would have provided a 100-fold reduction for CAT-I approaches and a ten-fold reduction in accident rates for all IMC precision approaches. Autoland would probably have been more widely utilized with this decreased but adequate reliability since it would have been available at lower cost. Thus, paradoxically, excessively high goals can derogate safety. Similarly, certification to levels derived from unvalidated models is a futile exercise. E&D should be devoted to gathering the data necessary to validate models.

In a similar vein, allocation of E&D resources must be made in a manner which produces the largest incremental safety gain for the associated resource investment. This cost/benefit consideration must be tailored to each segment of the aviation community. Cost/benefit criteria are not constant among the various user groups, but depend on the acceptable risks and burden of costs associated with each. Cost/benefit analysis must not be a mathematically sterile excerise, but must be illuminated by technical and operational experience.

18. The user community is also concerned about the need for improved integration of E&D programs within the E&D structure of FAA, with other

relevant organizations in FAA and with users and manufacturers. The troubled introduction of autoland is an example of the problem. Pilots first attempt automatic landings under better visibility conditions than the minimum certification of their equipment. This provides early familiarity with the equipment in a forgiving environment. However, the ILS signal quality is less satisfactory in this environment than under poor visibility conditions, such as CAT II, when aircraft must avoid areas that adversely affect the ILS signal quality. The autoland system follows the ILS vagaries faithfully, but the pilot is ,sure he can accomplish a better landing manually, so the pilot decouples, his familiarity suffers and his reluctance to use autoland increases. Unfortunately there are other inconsistencies between some ATC procedures and autoland capabilities. Furthermore, the reliability specification is unrealistically high. Therefore its complexity is great and maintainance expensive. When aircraft operators realize autoland is not used frequently by pilots, they are less fastidious about its maintenance. This discourages pilots even more. Obviously, coordination between pilots, manufacturers, operators, FAA flight standards and MLS advocates is needed if autoland is to become a reality as NTSB suggests. Could an organization or process within FAA coordinate all the participants in an effort to achieve utilization of autoland?

Another example has to do with airport capacity. Exquisite integration is needed between runway, exit and taxiway design, terminal automation, M&S, wake vortex avoidance, MLS and surveillance of the surface and the terminal airspace, in order to squeeze capacity into airports safely. Could an organization or process within FAA perhaps as an extension of the present Airport Task Forces - integrate the various E&D, construction, operational and institutional components needed to improve airport capacity on a site specific basis?

One last example deals with upgrading the air traffic control process in centers and terminals. This is a huge and necessary undertaking. The development of the desired ATC capabilities requires significant effort in two areas: first, the establishment of new automation concepts, the related operational procedures and the corresponding computer algorithms; second, the procurement and implementation of the necessary hardware and software to support the automation requirements. The first of these two tasks may well be the most time consuming and difficult since it involves exploration of some fundamental changes to the ATC process itself. A somewhat comparable upgrading of a real time computer complex in the Bell System, the Electronic Switching System #4, took a "team of fanatics" two years in preliminary design, then five years for the delivery of the first article and 400 million dollars. The FAA must obtain whatever manpower and money is required to accomplish this vital program.

19. The removal of rotating beacons from airport terminals and compass locators from outer markers has caused pilots unnecessary difficulties measured against the trivial cost of maintaining these facilities. In some cases, pilots will not accept a visual clearance to an airport on a clear night because they cannot identify the terminal against a background of urban lighting in the absence of a rotating beacon. This decreases airport capacity and increases controller work load. While this issue is not as significant as most E&D policies discussed previously, it is included here to illustrate the value of formal user consultation.

The users in the topic group that dealt with Non- and Low-Capital Policies to Improve Efficiency rejected the use of pricing-mechanisms to achieve efficient allocation of runway capacity. Some non-users disagreed with the users - notably the topic group chairman who concluded his minority statement as follows:

> "...a legitimate economic case can be made for augmenting reliever capability and capacity in metropolitan areas, a task which could be most efficiently addressed through regional planning and implementation of airport budgeting. It should be noted that the financing needs may extend beyond operating budgets, concrete and hardware: transfer payment to host communities to balance out externalities may be required. The concurrent implementation of an efficient demand allocation program (via pricing) might conceivably succeed if coupled with an appropriate supply augmentation program."

While a great many important and detailed recommendations are described in Chapters I through V and some have been abstracted in this introduction, it may be helpful to summarize here the major thrusts derived from this E&D initiatives process.

1. The users have a valuable contribution to make to E&D planning and appreciate being permitted to participate in this process. They have made specific recommendations which should be considered by FAA.

2. The en route and terminal air traffic control process is in need of a major upgrading to improve ATC productivity and the expedition of traffic. This process should permit some beneficial reallocation of roles between (a) pilot and controller, and (b) controller and computer to the benefit of the total system.

3. Better weather data are needed now by pilots and controllers. Users suggest -- among other things -- the development of en route radar with this objective rather than aircraft tracking.

4. The lack of airport capacity is a threat to all sectors of aviation and must be addressed by a priority process that deals simultaneously with all available E&D, construction and institutional alternatives.

5. Many of the issues examined by the users can be addressed through accelerated implementation of currently available E&D products. Although further E&D might be required in related or supplemented areas, such work should not interfere with implementation of programs or installation of equipment which has already received ample E&D.

NEW ENGINEERING & DEVELOPMENT INITIATIVES --
POLICY AND TECHNOLOGY CHOICES

SUMMARY AND INTRODUCTION

APPENDIX A

Biographies
of
Coordinator and Chairmen

Lawrence A. Goldmuntz
Coordinator

EDUCATION

B.E.E. - 1947, Yale University
M.E.E. - 1948, Yale University
Ph.D. - 1950, Yale University

PRINCIPAL INTERESTS

Public policy and its relationships to technology and the economy; application of advanced technology to engineering development.

EXPERIENCE

1972 - Present: President, Economics and Science Planning, Inc. (ESP).
1975 - Present: Visiting Professor of Engineering and Public Policy, Carnegie-Mellon University.

ESP activities: Resource allocation studies for the Electric Power Research Institute comparing R&D and implementation expenditures so as to maximize social benefits with particular reference to fluidized bed combustion and stack gas treatment; delineation of alternatives to improve the federal technical decision process, a study for NSF and OSTP; studies for the United States Railway Association and the Department of Transportation on the feasibility of the controlled transfer of bankrupt to solvent railroads as an option to solve the northeast and midwest bankruptcies; feasibility studies for the Gould Corporation of diurnal cold storage to minimize peak hour demand; studies for the National Science Foundation and industrial organizations on carbon monoxide monitoring versus carboxyhemoglobin measurements, toxic agents in sulfur oxide/particulate complex, sulfate aerosol transport modeling, benefit/cost ratios associated with automobile emission control strategies and with photochemical oxidant abatement; studies for the Urban Mass Transportation Administration and the National Commission on Productivity and Work Quality on public transportation service quality and productivity; report to the USA-USSR Joint Commission on Technology on Air Traffic Control as a Research and Development Project in the United States; reports to the National Center for Productivity and Quality of Working Life on Air Traffic Control Options to Improve Airline Productivity and Quality of Working Life on Air Traffic Control Options to Improve Airline Productivity and Regulatory Impacts on Airline Productivity.

Personal Prior Experience

1970 - 1972: Assistant to the President's Science Advisor, Director for Civilian Technology, Office of Science and Technology, Executive Office of the President; Executive Secretary to the Federal Council for Science and Technology; Chairman, ad hoc committee on Cumulative Regulatory Effects on the Cost of Automotive Transportation.

1968 - 1970: Consultant, Office of the Assistant Secretary of Transportation (Research and Technology); Chairman, Metroliner Steering Committee; Executive Secretary, Air Traffic Control Advisory Committee.

1953 - 1968: President, TRG, Inc.

1953 - 1965: General Manager, TRG Division, Control Data Corporation.

1965 - 1968: Supervised large-scale programs: shipboard sonar; space and terrestrial laser range-finding systems; airborne antisubmarine warfare systems; satellite communication ground station development; electronic countermeasures.

Robert E. Everett
Chairman, Topic Group 1

EDUCATION

B.S. - 1942 Duke University, Electrical Engineering
M.S. - 1943 MIT, Electrical Engineering

EXPERIENCE

April 1969 - Present: President, The MITRE Corporation.
March 1969-April 1969: Executive Vice President, The MITRE Corporation.
December 1959 - March 1969: Vice President, Technical Operations, The MITRE Corporation.
October 1958 - December 1959: Technical Director, The MITRE Corporation.
1956 - 1958: Head, Division VI, MIT Lincoln Laboratory.
1951 - 1956: Associate Head of Division VI, MIT Lincoln Laboratory.
1951: Associate Director, MIT Digital Computer Laboratory.
1947 - 1951: Associate to Dr. Jay W. Forrester, MIT Electronic Computer Division of the Servomechanisms Laboratory.
1945: Member of the Staff - MIT Project Whirlwind

SPECIAL ACHIEVEMENTS AND PUBLICATIONS

- Patent No. 3037192 - Data Processing System, Issued May 29, 1962.
- Patent No. 2988735 - Magnetic Data Storage (in conjunction with R. L. Walquist), issued June 13, 1961.
- "The Whirlwind I Computer", Review of Electronic Digital Computers - Joint Computers AIEE-IRE Conference, December 1951.
- "SAGE - A Data Processing System for Air Defense", R. R. Everett, C. A. Zraket and H. D. Benington, Procedings of the Eastern Joint Computer Conference, Washington, D.C., December 1957.

Joseph D. Blatt
Chairman - Topic Group 2

1. Education - Hold both a Bachelors Degree in Engineering and a Masters in Civil Engineering from the School of Technology, College of the City of New York.

2. Registered Professional Engineer, State of Missouri.

3. From 1937, to 1970, with the Federal Aviation Administration and its predecessor organizations in various technical and administrative positions ranging from Junior Civil Engineer to Associate Administrator for Development. Worked in regional offices in Atlanta, Kansas City, and New York, as well as the Washington Headquarters. Held such positions as:

   Junior Engineer, Atlanta, Georgia
   Chief, Engineering Division, Kansas City, Mo.
   Chief, Planning and Control Staff, New York, N.Y.
   Assistant Administrator for Planning, Research and Development, Washington, D. C.
   Regional Administrator, New York, N. Y.
   Deputy Director, Facilities and Materiel Service, Washington, D. C.
   Director, Aviation Research and Development Service, Washington, D. C.
   Associate Administrator for Development, Washington, D. C.

4. In these various positions, I actively participated in the development and deployment of today's airways and airport system and played a significant role in producing the best air traffic control and navigation system in the world today.

5. Under my direction research programs to develop safe aviation fuels, to develop crash survivability parameters, to develop noise abatement methods, procedures and techniques, and to quantify aircraft handling characteristics were initiated.

6. Co-chaired the NASA/FAA Research and Development Committee.

7. I pioneered research work that lead to a better understanding of the classification of soils as subgrade material under airport pavements; introduced area navigation concepts; and produced the engineering design philosophy and concepts upon which the air traffic control system of the 1970s will be built.

8. As Chairman, Joint Air Defense Planning Board, I developed the air defense concept of flight plan correlation of unknown radar targets and established the air defense identification plans in use in Continental U.S., Hawaii, and Alaska.

9. During World War II, I was assigned as a consultant to the War Department for the design and construction of airways and airports and installation of air navigation facilities required to support the U.S. Army Air Force South Atlantic Ferrying Operation.

10. Was designated as Head of U.S. Delegation and U.S. Spokesman at many international (ICAO and IATA) meetings and conferences.

11. Functioned as a visiting lecturer at the Air University, Maxwell Air Force Base; Post Graduate School, U.S. Naval Academy; and University of California at Berkeley. Lectured on Air Traffic Control, Air Navigation and Air Transportation.

12. Taught one semester in the evening session at the School of Technology, College of the City of New York - "Airport Planning and Design".

13. In March 1969, was honored by the School of Technology, College of the City of New York, on the occasion of the 50th Anniversary of the founding of the school. I received one of seventeen medals awarded to outstanding graduates of the school.

14. Received the FAA Exceptional Service Award, the Agency's highest award. Also received the FAA Administrator's Career Achievement Award.

15. Fellow, American Society of Civil Engineers. Past Chairman, Executive Committee, Aerospace Transport Division.

16. Member, National Press Club, National Aviation Club, Wings Club, Society of Airway Pioneers.

17. Since February 1970, I have been operating an aviation consultation service, providing advice and assistance on aircraft, airport, air traffic control and navigation, air transportation and guidance and control problems.

Gilbert F. Quinby
Chairman, Topic Group 3

EDUCATION

B.S. - 1942, Oregon State College

EXPERIENCE

1970 - Present: Senior Vice President, NARCO Avionics Division of NARCO Scientific.
1966 - 1970: Vice President, Marketing Planning, NARCO.
1960 - 1966: Vice President, Sales, NARCO.
1951 - 1960: Sales Manager, NARCO.
1946 - 1951: Sales Engineer, Aircraft Radio Section, Radio Corporation of America.

SPECIAL ACTIVITIES

1976 - Present: Vice Chairman, Radio Technical Commission for Aeronautics.
1973 - 1977: Member, Microwave Landing System Advisory Committee.
1973 - Present: Member, Executive Committee Radio Technical Commission for Aeronautics
1972: Observer Delegate, ICAO Seventh Navigation Conference, Montreal, CANADA.
1971 - 1972: Consultant to Aviation Advisory Committee.
1971: President, Aviation Distributors and Manufacturers Association.
1968 - 1969: Staff, DOT Air Traffic Control Advisory Committee.
1965 - 1966: Director, National Aviation Trades Association.

Roger J. Phaneuf
Chairman - Topic Group 4

EDUCATION

Ph.D. - 1968 MIT, Major Instrumentation
M.S. - 1964 MIT, Aeronautics and Astronautics
B.S. - 1962 MIT, Aeronautics and Astronautics

EXPERIENCE

Independent Consultant, 1978 - Present
Roger J. Phaneuf Associates

Providing assistance to aviation industry organizations with Federal government relations and equipment marketing, particularly in technical and operational areas. Specific activities include development of new systems concepts and assistance with FAA relations for the Safe Flight Instrument Corporation, assistance with FAA evaluation progress of new equipment for the SFENA Company and airline marketing assistance to the Simmonds Precision Company

Special studies performed for the FAA in areas of commuter aircraft equipment needs and safety analysis in the rule making process. Coordinated aviation industry review and evaluation of FAA Engineering and Development Initiatives.

Director - Engineering, Air Safety and Regulatory Affairs
1975-1978
Air Line Pilots Association (ALPA)

Management and budgetary responsibility for a department of technical and operational professionals, as well as fifteen pilot advisory committees. Duties included technical and operational advisor to the President and Board of Directors of ALPA, coordination of liaison with Federal agencies and Congress. Responsibilities involved preparing and delivering congressional testimony, communicating with news media and representing ALPA at industry and government meetings.

Congressional Relations Officer - Aviation, 1973-1975
U.S. Department of Transportation (DOT)

Represented the position of the DOT and administration on aviation policy and legislative proposals before the Congress. Developed and maintained channels of communication for congressional offices to handle constituency problems. Advised the FAA Administrator on political implications of rulemaking and other FAA actions.

Associate Director - Government Agency Affairs, 1971-1973
United Air Lines

Represented United Air Lines to various government agencies and to congressional personnel on technical matters. Also included in responsibilities were matters of regulatory policy at the Civial Aeronautics Board (CAB) and FAA, and international affairs at the Department of State. Presented to United recommended policy with respect to government operation, with emphasis on technical matters and corporate planning. Developed new channels of communications between United Airline officials and government leaders.

Engineering Test Pilot, 1970-1971
United Air Lines

Certified as Flight Engineer on DC-8 and B727 and as co-pilot on B727 aircraft. Responsible for test of aircraft after major overhaul, ferry of aircraft not serviceable, development of new equipment and acceptance of new aircraft.

Staff Engineer - Avionics, 1968-1970
United Air Lines

Provided technical management for the installation and on-line evaluation of a pictorial area navigation system in a B727 aircraft. Program Manager for the introduction of inertial navigation at United Air Lines. Responsible for installation of equipment in a DC-8 with associated FAA Supplemental Type Certification. Coordinated the development and certification of an overhaul repair facility and the development of a pilot training program. Directed the technical efforts of three other staff members.

Research Staff Member, 1962-1968
MIT Instrumentation Laboratory

Developed guidance equations for the Apollo spacecraft rendezvous and a monitoring system for Lunar landing guidance. Assisted in the development of a digital simulation of the full Apollo mission for verification of the guidance and control system. Directed three other staff members in research studies and assisted in teaching of two graduate level course in the Department of Aeronautics and Astronautics.

George W. Douglas
Chairman, Topic Group 5

Dr. George W. Douglas, President of Southwest Econometrics, is a specialist in the relationships between the public and private sectors of the economy. He has received the B.A. degree in physics and the M.A. and Ph.D. in economics, all from Yale University. While serving on the faculties of the University of North Carolina and the University of Texas, he taught graduate and undergraduate courses in economic theory, economic regulation, financial theory and markets, and transportation economics.

His published work in the fields of financial theory, economic regulation, and transportation economics has appeared in the American Economic Review, the Antitrust Bulletin, the Bell Journal of Economics, the Journal of Transport Economics and Policy, and Yale Economic Essays. He is also coauthor of the book Economic Regulation of Domestic Air Transport: Theory and Policy (Brookings, 1974), which has become a focal point in the current debate in Congress over regulatory reform in the airline industry.

Dr. Douglas was selected by the Brookings Institution as a Brookings Economic Policy Fellow to serve in the office of the Secretary of the U.S. Department of Transportation, where he assisted in the development of aviation policies. Dr. Douglas has served as consultant to or has prepared studies for numerous agencies including the U.S. Department of Transportation, the U.S. Department of Justice, the Federal Energy Administration, the General Accounting Office, and the President's Commission on Productivity and Work Quality. He has also undertaken consulting assignments for major industrial corporations and has appeared on numerous occasions as an expert witness before federal regulatory agencies and state public utility commissions.

NEW ENGINEERING & DEVELOPMENT INITIATIVES --
POLICY AND TECHNOLOGY CHOICES

SUMMARY AND INTRODUCTION

APPENDIX B

Work Statements
of
Topic Groups

APPENDIX B

Work Statements of Topic Groups

FAA wishes to examine five particular areas with users in greater detail then could be accomplished at this Consultative Planning Conference. To this end FAA has retained a contractor, Economics and Science Planning, Inc. (ESP) to help accomplish this objective. The five topics needing in-depth attention are listed below:

1. Productivity and Automation
2. Airport Capacity and Route Optimization
3. Freedom of Airspace
4. Safety and Flight Control
5. Non- or Low-Capital Policies to Improve Efficiency

The examination of each topic will be led by a chairman who has been selected for his expertise and familiarity with users' problems and the public interest:

Mr. Robert Everett - Productivity and Automation

Mr. Joseph Blatt - Airport Capacity and Route Optimization

Mr. Gil Quinby - Freedom of Airspace

Dr. Roger Phaneuf - Safety and Flight Control

Dr. George Douglas - Non- and Low-Capital Policies to Improve Efficiency

Dr. Lawrence Goldmuntz of Economics and Science Planning, Inc. will coordinate the examination of these topics with users and independent and government experts. It is expected that the groups examining these topics will meet approximately twice per month for a period of 7-8 months. Each chairman is responsible for preparing a report that is responsive to the topic work statement and that represents the views of the members of his group.

You are invited to join in the examination of these topics. Should you wish to do so, please fill out the form provided and leave it in the designated container. Alternatively, you can mail these forms to Economics and Science Planning, Inc., 1200 18th Street, N.W., Washington, D.C. 20036.

1. Productivity[1] and Automation

The cost of operating the ATC system has increased in recent years. Projections show that without productivity improvements, ATC staffing would increase more than two-fold by the year 2000. It has been hypothesized by some that before the end of this century we could reach a point where it would not be possible to effectively use more controllers and that the capacity of certain airspace could be "controller limited". Further additional services are being requested by many users of the airspace. Therefore it is necessary to increase the traffic handling capabilities of controllers both in the terminal and enroute airspace. While the achieved safety record of the ATC system is very good, errors do occur and FAA considers it essential to contain and reduce their occurrence. As the density of airspace use and the traffic per controller increases, the intrinsic safety of the control process must be maintained and if possible improved.

FAA is proceeding with the development of various automation aids and concepts such as DABS, ATARS, AERA, ETABS, TIPS, and ATS, all of which impact the productivity and safety of the ATC system[2]. DABS is a discrete address beacon system to improve surveillance performance and to provide a ground-air-ground data link capability; ATARS is an automatic traffic advisory and resolution service that will automatically provide a pilot with information about traffic of concern to him and as necessary provide conflict resolution information via data link; AERA is an approach to automating enroute ATC that would automatically monitor all controlled flights and generate conflict-free clearance; ETABS is an electronic tabular display system that eliminates the need for paper flight strips and minimizes repetitive time consuming controller input actions; TIPS is a terminal information processing system that will accept, process, distribute and display flight and other non-radar data in terminal control facilities and towers (it will replace the existing strip printer and not only reduce controller coordination but will improve the availability and timeliness of data); and ATS is an unmanned, low-cost alternative to a tower installation that would provide a completely automatic surveillance and communications system to provide advisory services to airports without towers.

a. Level of automation

How far should we go toward automating the functions now performed manually by air traffic controllers? The "routine" nature of many manually performed control functions has led to system errors. Automation of "routine" clearances would tend to decrease system errors. However "nonroutine" events, such

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1/ Productivity is defined to include all factors - manpower and capital.

2/ One should not infer that decisions to develop a system implies a decision to implement the development.

as equipment failures may require human intervention and the controller would have to be proficient and able to intervene in these cases. Evaluate the work accomplished by MITRE, SRI and FAA on the productivity and safety implications of past, current and potential attempts to increase the automation of the Air Traffic Control Process. If additional automation can improve productivity and safety -- what specific activities should be undertaken -- what should be the time scale and funding level of the program -- what would be the cost/benefits of such a program -- how can the productivity and safety benefits be evaluated?

b. <u>Computer and communication requirements and opportunities</u>

The computers in enroute centers are showing some evidence of saturation under demands for additional services. The terminal computers may have to be supplemented as conflict-alert, Metering and Spacing and other services are implemented. FAA may implement an Automatic Traffic Advisory Radar Service at DABS sites to reduce hazards. This same service may be expanded to provide cockpits automatically with information on nearby traffic as a routine service for those aircraft finding such information useful. Evaluate FAA needs for new computer capability at surveillance, terminal and enroute sites and compare these needs with the capability of available and forecasted computer hardware and software.

What are the implications with respect to reliability, diagnostics, acquisition costs and flexibility of the newer computer technologies? What are the advantages and disadvantages for FAA in attempting to achieve common computer technologies at some point in time? What architectures and software are susceptible to achieving the degree of reliability, flexibility and networking that FAA requires? To what extent can remote monitoring of computational equipment be effective in moderating maintenance costs? What levels of redundancy are appropriate, within a center, site or IFR room, between centers backing up each other, between sites, between IFR rooms and centers? What are the problems associated with inter-facility communication cost and reliability especially when attempting to achieve higher levels of automation that may involve inter-facility redundancy requiring substantial data exchanges between facilities? To what extent can satellite communications technology satisfy this requirement more economically and reliably than the current leased line and microwave system?

c. Man-machine interface

As higher levels of automation are attempted in any complex control process, the man-machine interface becomes increasingly important. How can a more highly automated ATC system be developed so that its general status can be displayed to a controller? How can a control problem that has not been resolved by programmed algorithms be displayed to a controller? Is an unresolved conflict alert a sufficient (as compared to necessary) trigger to call for display of control problems to a controller? Up to what density of airspace and complexity of routes can algorithms be developed to provide conflict resolution given present data rates and accuracies? How would the higher data rates and accuracies that could be achieved by DABS transmission of MLS derived data impact the answer to the previous question? To what extent can a hierarchy of automatic control be developed -- that is a translation of a flow control or a diversion or a rerouting requirement down to individual aircraft instructions? Is the availability of such a hierarchy an essential element in additional automation efforts?

If we find we cannot design a system that a controller can take over in case of major failure, how far must we proceed in designing a system that is failure proof and at what cost? Should FAA strive for "fail-operational"[1] capability of the automatic system or should we try for "fail-safe" systems, possibly with airborne CAS backup?

d. Cockpit - controller responsibilities and interfaces

Technological developments in automation, data collection, and dissemination and display technology can provide the cockpit with ground derived data that may increase productivity and safety in various segments of flight. How should responsibilities be apportioned between the pilot and controller in a more automated environment in order to achieve increased safety and productivity? What are the information requirements of a pilot in a more automated environment and what are the best ways of providing such information?

FAA is undertaking a sustantial program to evaluate the requirements for cockpit instrumentation in the evolving ATC system, assessing technological developments in automation, data collection, processing and dissemination, and display technology. One element of this effort is the examination of the utility of cockpit display of ground-derived traffic data,

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1/ A failure without loss of operating capacity

recognizing for example that this data may contain errors or gaps. The provision of cockpit information offers the opportunity for a backup to a more highly automated enroute control process and also possibly could be a way to achieve greater runway capacity. Such technology could be used as the basis for establishing the balance between the responsibilities of the ground control system and the pilot.

Is the display of the pertinent traffic in the cockpit a desirable or necessary additional backup to a highly automated ground control environment? Should it be provided as an additional ATARS function, presenting only traffic which may affect the particular aircraft's clearance?

The FAA is attempting to reduce pilot and system errors by a number of techniques, for example by the extension of conflict alert to terminal airspace, by the use of ETABS and TIPS in the enroute and terminal ground environment and by continuing to review the adequacy of pilot and controller proficiency checks. Would system errors be reduced by:

(1) Requiring altitude alerting and perhaps a feedback from the altitude alerting system to enroute or terminal ATC via DABS data link? Coupling altitude clearance to the autopilot as well as the altitude alerting system?

(2) Providing backup of the control system by ATARS and/or a cockpit display of relevant traffic when in the DABS era routine clearance messages might be transmitted --after passing a conflict test -- without specific controller approval? Is this likely to improve control system safety and controller performance and productivity?

(3) Acknowledgement in a digital format by the pilot for retransmission via DABS to the control computer of routine clearances? Are the "WILCO" and "UNABLE" acknowledgements in the proposed DABS implementation sufficient confirmation of a digitally displayed clearance -- should the acknowledgement be by keyboard entry of the clearance or are there other better ways of providing confirmation of the clearances?

(4) Continuing to provide voice clearances (possibly computer generated from the DABS messages) so that the cockpit has voice cues as to the clearances being provided to nearby aircraft when digital clearances are provided by the DABS data link?

(5) Continuing to provide voice cues as to other aircraft clearances even if ground-derived traffic information for cockpit display were to be provided. In the event that cockpit displays are found attractive, will it be necessary for FAA to transmit voice and digital clearances as well as traffic data for cockpit displays?

(6) Generating conflict-free terminal vectors by an M&S system and transmitting them automatically?

(7) Being able to provide both terminal and enroute conflict resolution "non-routine" clearances for transmission via data link to the cockpit either before or after clearance by the controller?

e. Role of primary radar

As the Secondary Surveillance Radar system evolves to the *Discrete Address Beacon System* with its automatic data link capability to provide automatic separation advisory and command functions, what should be the role of primary radar, if any?

f. Evolution to advanced systems

Advanced conceptual systems that could be considered for application in the 1990 time frame are being addressed in FAA's current E&D program. What role should proposed satellite systems such as NAVSTAR and Aerosat play in the future system? What factors do users suggest be taken into account in any proposed transition to satellite technology? Do the users perceived that there are basic reasons why an integrated, and therefore an interdependent surveillance, navigation, communication and control function should be pursued, or in fact, should it be rejected? Should FAA consider the evolution of the integration of the communication, navigation, and surveillance functions using satellite systems?

2. Airport Capacity and Route Optimization

Congestion at major terminals is expected to become more severe in the future unless additional capacity is provided. Even with expected short to intermediate term gains from FAA's current major development programs, demand projections show a shortfall in capacity will occur in the mid-1980s and beyond unless airport improvements and advanced development concepts for the ATC system are implemented. Coincident with growing congestion of the runway and terminal airspace system, there is a growing capacity problem in passenger terminal areas and airport access.

Currently, total aircraft operating costs, due to delay, are estimated to be about $500 million/year. These are projected to exceed $1.5 billion/year by the mid-1980s unless capacity is increased and routings made more efficient. These delay costs are more than the maximum net profit ever achieved by the domestic trunk carriers which was $439 million (in 1977). If they occur as projected, these delays could represent a constraint to aviation growth.

FAA, working with airlines and local airport authorities, is currently gathering hard facts bearing on this problem at each of eight major capacity constrained airports. Being assessed are current and projected capacity and delay levels; what can be done to increase capacity by improving the runway/taxiway configurations and methods of operation; and what increases might be realized in the future through the use of products from the current E&D program. The FAA is expanding its initial effort of analyzing eight major airports to include 12 additional busy hub airports that either have capacity problems now or are projected to have capacity problems in the future.

Major technical questions relating to this issue deal with the extent to which FAA can or should develop and implement technological improvements as compared to investing in new airports. Major policy questions relate to whether there are more equitable ways to use runway concrete to obtain the best payback in airport investment and whether it may be desirable to implement low and non-capital options and institutional alternatives including ways to make more efficient use of transfer and reliever airports. These low-capital options are treated by another task force.

a. Technological Options to Improve Airport Capacity

(1) Can airport capacity under IMC be made more nearly equivalent to that under VMC? The FAA is aware of the following possibilities: Provision to the cockpit of information

relating to the lead aircraft; the improved performance and variable approach capability of MLS; the use of M&S (Metering and Spacing) to improve aircraft delivery accuracy as well as to aid in the staggered delivery of aircraft to intersecting or parallel runways that are not independent; the provision of runway occupancy information simultaneously to both the cockpit and controller by a TAGS (Tower Automated Ground Surveillance) system; the possibility of MLS or RNAV precision guided departures so as to minimize airspace and runway interferences. What other possibilities are available?

(2) M&S (Metering and Spacing) systems have been under development for some time. An M&S simulation of Denver utilizing ARTS III will be conducted this winter at NAFEC with the objective of achieving an interarrival accuracy (1σ) of 11 seconds at the approach gate and eventually 8 seconds in more advanced systems. In order for terminal M&S to work it may be necessary to achieve aircraft deliveries with a 1-minute accuracy at the feeder fix in accordance with the plan established by the terminal M&S system. Can an M&S system be developed to provide conflict free vectors so as to achieve the desired delivery accuracies? Can aircraft under various wind conditions and with the average pilot, respond to M&S instructions so as to achieve the desired accuracies? Can an M&S system be developed to feed multiple parallel and intersecting runways with the desired staggers in arrival time? Can M&S aid in releasing departures so as not to interfere with subsequent arrivals or prior departures on a complex set of runways?

(3) Review the wake turbulence avoidance systems, both basic and advanced, as well as possible changes in flight control instruments and procedures to determine whether longitudinal separation can be reduced under wake turbulence meteorological conditions and whether the frequency of occurrence of wake turbulence is as indicated in the case studies of airport capacity.

(4) Are the predicted improvements in capacity due to speed-class or wake-vortex class sequencing likely to be achieved if the first-come - first-served principle is modified during peak periods of delay?

(5) Can it be demonstrated that "closed loop command-control" of aircraft in approach (and departure) operations will result in a significant increase in airport capacity?

(6) On final approach, would information on aircraft on parallel approaches, derived from DABS or other means[1] and displayed in the cockpit, allow independent operations under IMC on parallel runways at closer separations than now permitted? Would this result in elimination of separate approach monitoring of the "no transgression zone" for independent approaches to parallel runways?

(7) A number of studies point to the capacity limitations of the airport terminal building area and airport access as being a major constraint to airport capacity in the future. What types of E&D, if any, should FAA be doing in this area? Assuming runway capacity can be improved to serve forecast traffic, would airport operators and local authorities be able to increase the terminal building area capacity and airport access capacity to accomodate such increases?

(8) FAA has a number of efforts underway that relate to inefficient routings. For example, a restructuring of enroute airspace might permit the use of more efficient altitudes on the New York to Washington routes. However, this would increase the workload of certain sector controllers due to crossing traffic flows. The Advanced Enroute Automation (AERA) program has as one of its objectives, a reduction in controller work load and might make such a restructuring feasible thereby providing optimum altitude routes between city pairs. RNAV, based on the current navigation system can also provide direct routings and simplified navigation in terminal airspace. INS is now used for direct routings on long distance flights. What are the technological and institutional barriers to greater use of efficient routings and what are the benefits from such routings and what programs should FAA undertake to overcome these barriers?

(9) How can the noise abatement influence on capacity be ameliorated?

1/ For example, ILS or MLS data relayed by DABS data link.

3. Freedom of Airspace

The risk of collision, in theory, increases faster than the density of traffic. Furthermore, traffic density is forecast to increase substantially in the future with the predominant growth in the use of controlled airspace expected to be general aviation IFR traffic. These factors tend to increase the requirement for airborne equipment and procedural techniques to aid the surveillance process.

How can FAA develop a system that permits the maximum freedom of airspace use to both large and small aircraft of various capabilities at the lowest possible financial and environmental cost and highest practical level of safety? Does increased automation, which may require improved surveillance and more extensive use of transponders, permit a more flexible route structure and greater freedom in the use of the airspace?

a. Transponder usage

Would mandatory equipage of Mode C transponders (ATCRBS transitioning to DABS with data link) on aircraft, in addition to providing productivity and safety benefits, serve to provide greater flexibility for uncontrolled aircraft desiring to fly in or near high density airspace? This greater flexibility could result from the increased capability of the control system to provide traffic advisories to controlled aircraft in mixed airspace and because of the potential ability of BCAS systems on sophisticated aircraft to provide "last-ditch" back-up separation assurance against Mode C transponder equipped aircraft in low density airspace.

b. Role of DABS data link

Can the data link capability of DABS permit a better level of controlled-VFR service in TCAs? The FAA is considering services based on DABS (or ATCRBS where appropriate) such as Automated Terminal Service at unmanned terminal facilities, the relay of appropriately filtered traffic information, proximity warning and collision protection from other aircraft or terrain. Other services are possible. Among them are: Hazardous weather advisories, ATC take-off clearance confirmation, ATIS-type data (Automatic Terminal Information System), altitude assignment confirmation, active-runway threshold winds, etc. Are there other data link services, that could and should be provided? For example, should DABS/ATARS be utilized for vectoring general aviation pilots automatically in dense terminal airspace?

c. Airspace structure and coverage

Are there ways of structuring and monitoring the airspace to permit freedom of operation without requiring ATCRBS or DABS transponders while still insuring safety in mixed and positively controlled airspace?

d. Other costs of increased freedom of airspace

Will shifts or increases in aircraft noise impacts due to technological or other system changes create limitations on the actual use of those changes?

4. Safety and Flight Control

While aviation safety has improved dramatically over the years, the forecast of more air traffic activity and larger passenger loads per aircraft underlines the need to continue to improve the safety of aviation. This question is inseparably related to the issues being addressed by the productivity and capacity task forces. This task force is being asked to deal with establishing adequate safety levels, decreasing approach and landing accidents, and providing backup separation assurance and weather services.

a. Establishing adequate safety levels

There is some evidence that reliability levels for certain airborne components have been established at unrealistic levels.[1] What are the best methods for establishing and measuring the safety levels for certification of air and ground systems?

b. Approach and landing accidents

(1) Evaluate the current FAA programs that are designed to provide better warning of wind shear and hazardous weather. Should wind shear and hazardous weather warnings be transmitted to both the controller and cockpit automatically by computed generated voice or DABS?

(2) The NTSB has concluded that "Greater use of the autopilot approach coupler will augment instrument approach safety." Evaluate this conclusion and determine the technological and institutional barriers to its implementation. There are some indications that completely automatic landing systems hold the promise of saving 80 to 90% of the lives lost in landing accidents at a level of reliability perhaps one-tenth of that for which they are designed. Evaluate these possibilities. There are some proposed modifications to flight control systems that presumably counteract wind shear effects. Evaluate these systems and determine whether they are sufficiently developed and important to be recommended or required on various classes of aircraft.

(3) There are some indications that precision approaches are considerably less dangerous than nonprecision approaches for the same IMC conditions. What approaches are there to provide better and cheaper precision landing aids at general aviation airports?

(4) There are some indications that runway lighting systems are effective in good visibility but poor compared to

daylight in low visibility. What can be done to correct this situation? As precision non-visual aids become more available, is there a need to continue the development of improved visual aids beyond the ones currently in the program such as TVASI (T-Visual Approach Slope Indicator) and FAME (Final Approach Monitoring Equipment)?

c. Separation assurance

There is a small, but troubling problem of system errors and near mid-air collisions in all airspace. FAA is planning the extension of conflict alert to high density terminal airspace, is considering implementation of ATARS, and is pursuing the development of BCAS to address this issue.

ATARS and BCAS are intended as backup safety elements to minimize the consequences of pilot and system errors. The traffic advisory and conflict resolution indications are expected to be advisory to the pilot, but would be provided without prior clearance by the ATC system because of the limited time to a potential hazard. ATARS operates in regions where there is DABS coverage. It may be that BCAS can operate only where the traffic density is low to moderate and outside the traffic pattern. An FAA program is being undertaken to overcome certain of these BCAS limitations.

In high density terminal airspace conflict-free clearances are provided for controlled aircraft. If a conflict then develops, there may not be sufficient time to develop the conflict alert and the conflict resolution for presentation to the controller for his approval and transmission over standard communication channels. Therefore, in this case, it is planned that ATARS would provide resolution instructions via the DABS data link to all involved DABS equipped aircraft simultaneously with its presentation to the controller. If ATARS looks ahead for 30 seconds it has been calculated that one alarm would be generated per hour in one sample of high density airspace under VMC. The alarm is triggered by projected flight vectors indicating a projected violation of an alarm volume; it is not triggered by the violation of separation standards but by a probability of collision. The accuracy and frequency of the surveillance data and the maneuver rate of aircraft influence the ability of projected flight vectors to predict a collision.

Are the alarm rates sufficiently low under current and projected traffic densities and the safety levels achieved sufficiently high or should FAA consider various additional alternatives such as restructuring of troublesome airspace, utilizing greater accuracy and higher data rate information that might be obtained from terminal area MLS and relayed by a

DABS downlink and utilizing air derived as well as ground derived data in deriving ATARS?

If climb/descent rates are more rigidly controlled as final altitudes are approached in order to minimize overshoots, there might be fewer "busted" clearances and fewer ATARS advisories. What procedures or technological fixes can be employed to minimize violated altitude clearances?

What priority should be assigned to BCAS implementation since ATARS, if implemented, can back up the control process both in enroute and terminal airspace that is covered by the DABS surveillance system?

Should FAA require top and bottom mounted ATCRBS or DABS antennas on certain classes of aircraft so that ATARS can be provided in terminal airspace even when these aircraft are banked and shielding their antennas from the ground interrogation beacon?

d. Weather services

According to NTSB reports, weather is a contributing factor or cause in about 40% of all fatal accidents. Typical among the factors are low ceiling, fog, rain, and continued VFR flight into adverse weather.

FAA has a number of programs for improving weather services. FSS modernization includes several improvements to mass weather dissemination and weather briefings. Further, FAA has under development an automated low-cost weather observation system (ALWOS) for use at general aviation airports with approved instrument approaches which currently do not have local observations. In addition, FAA has under development a semi-automated weather observation system for use at air traffic control towers designated to take weather observations.

Are there additional programs that FAA should undertake? What should be the next steps in the development and provision of improved weather services? Should warnings of severe weather be gathered automatically from aircraft and relayed to concerned aircraft via the DABS data link?

5. Non- or Low-Capital Policies to Improve Efficiency

Demand projections suggest that a shortfall in capacity will occur in the 1980s and beyond unless improvements are made. Improvements can range from capital intensive actions to those that do not require capital. Noncapital or relatively low capital actions to reduce airport congestion range from those which are primarily administrative to those which are of a purely economic character. These measures generally do not expand airport capacity in the physical sense of making possible more aircraft movements per unit of time. They can, however, postpone the need for expansion of airport facilities by rationing runway usage or by tailoring runway usage to an optimum desired level or mix of users.

Such options would include (1) peak hour pricing, (2) greater use of satellite and secondary airports, (3) restricting access to airports through quota systems, (4) restricting access to airports through specific route awards (a CAB matter), (5) prohibition of certain types of flight activity or users, such as touch and go landings or student pilot flights, (6) selective use of discount fares to spread demand, and (7) schedule allocation across periods of times to reduce peaks whenever saturation is inherent.

There are several characteristics of the system that suggest that one or a combination of these options would reduce delay while enhancing utilization of existing facilities:

First, demand for airport use usually peaks at one or several times during the day causing congestion and delay. If demand were smoothed throughout an operating period, less delay would accrue for an equivalent level of traffic handled.

Second, the economic value that different users derive from airfield availability varies according to type of aircraft, time of day and locality, among other things. The point is often made that society would benefit most if users who derive the greatest dollar benefit or who transport the greatest payload of passengers or cargo were allowed priority access to scarce runway space.

Third, different airport users require varied on-airport equipment and capabilities.. Larger commercial aircraft, for example, have more demanding requirements for runway lengths, strengths of pavement, and electronic instrumentation than do other categories of users. Facilities for most other users are less expensive to build, operate, and maintain.

On the other hand, some claim that such noncapital or low capital options are unnecessary, that the system will take care of itself. Others say that these options will not reallocate or spread demand -- that delay is reduced only by reducing demand for air transportation. Still others claim that such options would disrupt air carrier route structures and the ability of local service and commuter carriers to "feed" into trunkline service.

This task force should address the following questions:

a. Can air carrier demand be expected to abate by increases in load factor and higher seating capacity of aircraft? If so, to what extent and in what time frame?

b. What are the true costs of delay; i.e., the net revenue foregone from not having a specific flight versus the additional cost imposed by the delay generated by that particular flight?

c. What is the tradeoff between passenger inconvenience (not always being able to travel at the "desired" time) and the savings in fuel and other costs through higher load factors?

d. To what extent should the Federal government involve itself in rationing runway usage or in seeking optimization of airport usage where congestion and delay have reached high levels?

e. Most airlines optimize their flights at major airports for interconnections. Congestion and delay often are by-products. At what point should regulatory authority involve itself in schedule allocation or prescribe the use of underutilized airports for interconnection?

f. Under what circumstances does it become attractive to airlines and other users to flatten peak demands at major airports through their own devices?

g. What has been the experience with respect to discount fares:

(1) New traffic generated -- both passengers and flight operations?

(2) Traffic diverted from other time periods?

(3) Traffic diverted from other airlines?

(4) Other?

h. What institutional and legal barriers exist that reduce or restrict the ability of airport management to impose time dependent fees?

i. What level of fees would be required to shift demand from one time period to another?

j. Under what circumstances would the users, themselves, shift to less crowded airports in major hubs -- for example, Newark, Midway, and Dulles, or make use of other interchange airports so as to reduce demand at, for instance, O'Hare and Atlanta?

k. Are reliever airports adequately located and equipped to be able to handle traffic under even adverse weather conditions, so as to attract aircraft from major hub airports? If not, what can be done to improve the situation?

l. Would it be desirable to select a key, high density airport or metropolitan area for the testing of various low or noncapital administrative and economic actions for reducing congestion and delay?

m. Small changes at some airports can provide increased capacity. For example, some believe that use of the high speed exits at Denver or their relocation toward the terminal could decrease runway occupancy time by as much as 20%. How do we provide incentives to use those exits that clear the runway fastest rather than those that are closest to the terminal?

NEW ENGINEERING & DEVELOPMENT INITIATIVES --
POLICY AND TECHNOLOGY CHOICES

CHAPTER I

PRODUCTIVITY AND AUTOMATION
Topic Group 1

Final Report

PREFACE

This report is the result of the Automation/Productivity Group's deliberations, which occurred as part of the FAA's New E&D Initiatives activity. The body of the report (Sections 1 through 5) represents the views of the participants of the group's meetings. Appendix G of the report provides a list of the participating user groups, and the individuals who represented them. In addition, Appendix G presents a list of the participating members of industry who provided very useful inputs for the users to consider. Appendices A through F of the report document some of the inputs which were presented to the users by the industry and FAA people. Appendix D differs from the others in that it was developed by a subgroup of the overall Automation/Productivity Group, which included some user participation as well as industry participation. In the case of all of these appendices, the users do not necessarily agree with or endorse the presented information, but did consider them as useful to their deliberations.

AUTOMATION/PRODUCTIVITY E&D INITIATIVES GROUP

1. OBJECTIVES

The Automation/Productivity E&D Initiatives Group (henceforth referred to as the group) has made an assessment of certain aspects of the present and future status of air traffic control processes in the United States. A number of important problems can be relieved by automation improvements. Automation can often be used to improve the ratio of the amount of traffic effectively handled to the amount of resources needed to handle this traffic. The resources in this ratio are air traffic controllers, airports, electronic equipment, and maintenance personnel and facilities. The amount of traffic measured against the amount of resources is defined as productivity. Problem areas are identified in this section, along with some indications of how automation might help.

Problem areas are viewed primarily in the context of future problems. This is not meant to imply that immediate system improvements are not both desirable and possible. However, the group recognizes that significant improvements and possibly even new approaches to air traffic control are needed if projected increases in traffic are to be handled efficiently with reasonable levels of resources. Moreover, because of the long development and implementation cycle required by major improvements, new programs must be initiated early to have new systems operational when they will be needed.

The major problem areas have been categorized into four areas:

(1) Increased terminal area productivity

(2) Increased en route ATC productivity

(3) Increased ATC operational flexibility

(4) Increased user confidence in automation

Each identified area is described in more detail below.

1.1 Increased Terminal Area Productivity

The need for increased terminal area capacity has been recognized as an important area deserving special attention. This need is being addressed by the Airport Capacity Group. The most critical productivity improvement to be made should be increasing the number of operations per hour, especially in IMC, that can be handled in the airport. Previous terminal

automation efforts have provided the ARTS III capability at 63 major air terminals with an associated controller productivity improvement of about 8% (here and in the following discussion productivity is the ratio of air traffic controllers to flights). Current FAA efforts have been directed to automating the flight data handling task by replacing the manual handling of flight progress strips with electronic distribution and updating of flight strips via alphanumeric displays. The efficiency achieved in flight data handling has been projected to improve productivity by roughly 20% at ARTS III locations by eliminating the need for some data coordinator/handoff positions and combining clearance delivery and flight data positions.(1)*

Automation might help to increase productivity by providing:

(1) Precise computations to help the air traffic controller improve metering, sequencing and spacing capability. This may include computation of suggested heading and speed commands for the controller's consideration.

(2) A data link capability to make it possible for the ground system to transfer final spacing responsibility to aircraft equipped with appropriate airborne capability, e.g., traffic display augmented with other ATC information such as the identification, aircraft type and final speed of the aircraft to be followed.

(3) Accurate display presentations for allowing the air traffic controller to deal with separation standards that can vary with aircraft type and time because of wake vortex considerations.

High density terminal area automation capabilities which go beyond aiding the air traffic controller are a difficult technical objective. Automation which computes commands for aircraft and automatically delivers them to the pilot via data link requires complex algorithms. This automation would also involve serious complications in successful human factors design. For example, one would need to develop a new role for the air traffic controllers operating such a system. Insight into human factors design is critical and hopefully this experience can be acquired in the less complex ATC en route environment.

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* See page 94 for References.

1.2 Increased En Route ATC Productivity

1.2.1 Automation

The group believes that en route air traffic controller productivity can and should be improved by making more use of automation in the control of traffic. In the past, the en route controller work force has grown in close proportion to increases in traffic. This relationship follows staffing standards used by the FAA which set requirements for the number of controllers needed in a sector and the size of a sector based on the expected peak traffic count. The current en route controller staff has about 10,200 people serving an annual traffic demand of roughly 25 million en route IFR handles. Traffic is expected to double by 1995. If past trends hold, the associated work force would also double.

Previous automation efforts have resulted in the implementation of NAS Stage A with an associated productivity improvement of roughly 10%. Further efforts are planned to assist with flight data handling tasks. The proposed flight data handling system would provide the en route sector controllers with an electronic tabular display of flight data instead of flight strip printers. By giving controllers an efficient way to communicate with the flight data base, the control position that deals with flight data at some sectors could be eliminated.(1)

Implementation of the near term automation programs that address data handling could result in increasing controller productivity to a level such that growth in traffic over the next few years would be absorbed by the ATC system with little increase in staffing. However, beyond that, the eventual doubling of traffic would result in demands which would be reflected in increased staffing, and possibly ATC system saturation. Saturating the ATC system would translate into increased delays and fuel penalties endured by the users, and would also result in more flights being scheduled in times that are not optimum from the point of view of the user or the flying public. To make even greater improvements in productivity, more advanced automation is likely to be needed that would directly involve the real time control of traffic via automatic clearance generation and automatic ground to air communication. Such automation could also provide pilots with additional information provided via data link to carry out certain separation functions, which are now the air traffic controller's responsibility. This would be a new role for both the pilot and the controller who must supervise this system.

If advanced automation could increase controller productivity by a factor of two, staffing could be held relatively constant over the period from 1985 to the year 2000 so that potential savings are estimated to be about 90,000 man-years.(1) In monetary terms, the (undiscounted) savings are in excess of $3 billion in terms of 1979 costs for air traffic controllers. While such benefits have obvious attraction, the development of a system capable of achieving these benefits is a huge and necessary undertaking. The development of the desired ATC capabilities requires significant effort in two areas: first, the establishment of new automation concepts, the related operational procedures and the corresponding computer algorithms; second, the procurement and implementation of the necessary hardware and software to support the automation requirements. The first of these two tasks is undoubtedly the more difficult because it involves exploration of some fundamental changes to the ATC process itself. However, the procurement and implementation process is also quite significant. This point is illustrated by a somewhat comparable upgrading of a real-time computer complex in the Bell System, the Electronic Switching System #4. As described in a briefing given to the group this development process took five years for the delivery of the first article and 400 million dollars.

It seems clear that even though the necessary computer hardware to support automation must be in place prior to implementation of new automation functions, development of the functions must go on concurrently with hardware design and selection activities. This will ensure that the desired new automation concepts and procedures are well understood and can be implemented as soon as the needed computer facilities are available.

1.2.2 Consolidation of ATC Facilites

Within the continental United States there are 20 Air Route Traffic Control Centers, 135 Advanced Radar Terminal Systems, (ARTS II and III), and one Central Flow Control Facility which already use or will shortly be using computers as a central part of their operation. In addition there are currently 292 Flight Service Stations for which automated systems are being developed, with the initial configuration to consist of approximately 43 automated FSS served by 14 centralized data processing systems. With technological changes in computers and communications and greater automation, this division of ATC facilities may not be the most cost effective approach. Furthermore, division of ATC facilities creates discontinuities in the ATC process which require automatic communications and

manual coordination between facilities to correct. For example, delays taken in the en route airspace are not presently credited to an aircraft when it arrives in the terminal, since the terminal air traffic controller has no knowledge of the past situation. This type of problem can be solved by increasing the automatic communication between facilities as the FAA is currently doing, or eliminating the communication requirement by consolidating facilities to share computer resources.

1.3 Increased Operational Flexibility

The current ATC control policy seeks to reduce the control problem to manageable proportions by establishing sectors of responsibility distributed to control teams. An en route control center's controlled airspace typically is divided into 30 to 50 sectors. Operating agreements are established among these teams to facilitate normal operations. Deviations from jurisdictional restrictions are granted only on a case-by-case basis and require coordination between air traffic controllers. This limits some desirable user operations like random routes that conflict with standard practices, since heavy coordination workloads can result. In addition, many reasons for jurisdictional agreements are not told to the ATC system user. This limits his ability to assist with the operation or to complement the ground system's limited data base.

1.3.1 Airspace Utilization

Serious system restrictions involve a limited capability to accommodate random routings in the ATC system, the use of restricted altitude ceilings for short flights in high density airspace, and the use of premature descents from the high altitude to the terminal area. The current system's reliance on fixed sectors of responsibility is often the source of these restrictions.

Altitude ceilings are a specific air traffic controller workload-related restriction on ATC operations. Aircraft are designed with a best fuel cruising altitude prescribed by aircraft weight. Since the aircraft weight is decreased as fuel is burned, the optimum flight altitude continuously increases. In high traffic situations, it is difficult to deal with a user's desire to either fly at his most desired altitude to start with, or to continuously change altitude. This is in conflict with the standard practice of segregating aircraft by altitude. A recent FAA study reviewed the potential for fuel savings on the LaGuardia Airport to National Airport route where these short distance flights are restricted to an altitude

ceiling of 16,000 feet MSL. By permitting aircraft to use a more fuel efficient altitude near FL 240, over 3 million gallons of fuel could be saved annually.

Automation in these operations could generate and coordinate clearances for intersecting traffic. It could permit merges of high altitude flights with the lower altitude flights desiring access to the higher altitudes. It could also allow higher traffic loads to be absorbed in the high altitude sectors without creating sector workload imbalances and overloading.

Premature descents are sometimes imposed on arriving traffic by fixed crossing altitude restrictions designed to segregate these aircraft from other conflicting flows. While profile descent procedures are being designed to minimize the use of such restrictions, those that remain can produce fuel penalties. A recent study estimated that the old step-down procedure for Denver high-altitude arrivals from the northeast consumed 100 gallons more fuel per average arrival than the profile descent procedure designed to replace it. To the extent that such restrictions separate aircraft from unoccupied airspace, instead of from other aircraft, fuel savings could be realized. Automation should make it possible to replace such fixed constraints by a more dynamic intersection control procedure. The potential annual fuel savings from achieving an ability to nationally apply unrestricted profile descent procedures has been estimated to range from 300 to 600 million gallons annually, depending upon how efficiently the metering and spacing process is conducted.

Because of decreasing costs, RNAV is becoming more widely available. Suitably equipped aircraft can now fly other than standard VOR defined routes. This capability used in en route and terminal airspace could permit the pilot to fly a shorter number of air miles. For example, if the flow patterns for air traffic in terminal areas were available, the pilot could proceed directly to his or her specified position. Control instructions would only be needed to avoid traffic. Pilot knowledge of the overall intended route would permit planning for efficiency. An FAA study projected the potential advantage of RNAV-based terminal routings over the conventional vectoring procedures to be about 3 billion gallons of fuel and 1.8 million hours of flying time for air carrier flights in the top 60 terminals over the 19 year period from 1982-2000.(2)

In en route airspace there would be some advantage to permitting direct routes rather than restricting flights to published routes. The benefit is not as great as it might appear, because of the near optimal placement of published routes. Probably the major advantages of random routes would be avoidance of adverse weather and use of lateral route offsets for optimal cruise altitudes on busy routes. The FAA study previously referred to projected the potential advantages of direct RNAV routes over the published high and low altitude routes to be 3.7 billion gallons of fuel and 1.9 million hours of flying time for air carrier flights within CONUS over the 19 year period from 1982-2000.(2)

Of course, these random routes tend to cut through sectors organized along standard routes. This creates potential conflicts at other than standard intersections. Advanced automation would provide automatic coordination among affected sectors and automatic detection of possible traffic conflicts to help permit more use of these random routes.

1.3.2 Information Distribution

Adding ground-air-ground data links to the cockpit would provide a new automation approach to information distribution. The current ground-based ATC system makes control decisions based on data which is sometimes unknown to the controlled aircraft. In addition, some pertinent airborne data is not available to the ground-based decision making process. The type of information that might be usefully shared includes weather, traffic, vectored routes, and aircraft mission data. Sharing of some additional information should result in a more smoothly operating system.

Weather data in the current system is derived from ground sensors and to a small degree from pilot reports. It is often incomplete. Airborne aircraft represent a large set of weather sensor devices that could provide up-to-the-minute data automatically or by request. Aircraft with sophisticated navigation systems could provide accurate wind aloft data which would be valuable in controlling the spacing between aircraft at specified traffic merging fixes and for use by other operators in flight planning.

The availability of traffic information in the cockpit potentially could be used to relieve controllers of work that can be done by pilots in designated instances, and might give pilots more airspace flexibility.

1.4 Increased User Confidence in Automation

To benefit from automation, air traffic controllers and pilots must have a very high degree of confidence in the automation system. The overall reliability of the future automation system hardware and software must be much better than today's system provides. This confidence is such an important requirement that it has been elevated to an objective in its own right.

En route automation system outages, of varying durations, occur with some frequency in the current NAS system. When the automation system fails for long periods, the control process reverts to a broadband radar presentation without alphanumeric identity or data. This mode requires the controller to convert his display to a horizontal position, to manually prepare shrimp boats to maintain the identity of the aircraft under his control, and to transfer all aircraft beacon assignments to non-discrete codes. This transition from NAS to broadband is accompanied by considerable controller anxiety. When the broadband presentation fails for long periods - as might occur with a power interruption or complete radar sensor or display failure - the system reverts to procedural control based on time reports at fixes and flight strip information. The transition from radar based control to procedural control requires the controller to adjust separation standards to higher values (10 minutes versus 5 miles for coaltitude aircraft). Needless to say, an outage which occurs instantaneously and without warning creates a tense control situation during the transition to the non-radar procedures.

System outages are difficult to evaluate on a representative national scale. Examples exist of periods where system reliability is high (e.g., on August 10, 1978 the FAA reported to the group that the Minneapolis ARTCC had experienced no down time in the last 55 days). Even though they are not representative, isolated examples also exist which create intense interest in improving system reliability. A recent FAA input to a Congressional hearing(5) indicated that during one forty day period in 1976 the Indianapolis ARTCC experienced 97 periods when the scope went blank or was frozen for 1 minute or less and 29 system outages of longer duration. The momentary losses were generally caused by software errors or manual ATC actions. The longer outages were also predominantly caused by software errors as well as power interruptions and intermittent hardware failures. During this period there was also a complete system failure, caused by a lightning strike and attendant power failure, which necessitated a fall back to procedural control. At the time of the failure there were 109 aircraft under the

active control of the Indianapolis Center. Five of these aircraft were involved in potential conflicts and revised clearances had to be issued to establish positive separation.

The FAA has recognized the impact these interruptions have on controller and user confidence in the system and have planned a number of short term solutions (e.g., upgraded power conditioning systems) and longer range improvements (e.g., a Direct Access Radar Channel to provide full alphanumeric identity and aircraft data in the event NAS radar display capability is unavailable). These improvements are expected to improve total system performance. However, the group recognizes the need for more comprehensive assessments of potential outages and appropriate solutions that relate to improved redundancy and increases in the inherent reliability of system components, particularly software.

If the FAA expects automation to play a more significant role in the future, it must gain more user confidence in automation. This should be a design objective from the start.

2. AVAILABLE TECHNOLOGY

Several technological developments make it possible for the FAA to pursue higher levels of automation. Major advances have been made in computer hardware cost and capacity and software development. In addition, the FAA is developing improved surveillance and data link capability in its Discrete Address Beacon System (DABS). In the air, computer advances have made area navigation cheaper. Because of computer and display technology advances some new aircraft will be equipped with on-board pictorial display systems. These systems could provide additional ATC information which might permit more pilot involvement in the ATC process.

This section will be more specific about the nature of these technological advances and how they might impact the FAA's automation plans.

2.1 Computer Hardware and Software

There have been and will continue to be technology trends that will affect computer hardware and software for the ground-based portions of ATC systems. The continuing decrease in hardware costs, resulting in changes in the economics of organization of computers, will allow more concentration on the primary life cycle cost factor: software. Achieving highly reliable software along with flexibility to incorporate the continuing technology advances should be key goals of future systems.

Two important system implications result from the advances in computer hardware. First, one is able, in a cost effective manner, to procure increased hardware capabilities as a means of simplifying the software job. For example, in spite of the hardware overhead implied, one can cost effectively decide to use higher level languages throughout a development, which improves the ability to develop, validate and modify software. Second, many options exist on how to configure the automation system. Architectures are no longer limited to being based on a large mainframe computer, but can include the use of distributed processors, or even more advanced network concepts which include use of a central data bus for communication between computers. Clearly, there are numerous performance decisions which must be made in choosing a specific hardware configuration, which are relevant to the FAA's systems. Appendix A presents a discussion on some of the implications that the choice of computer architecture can have on ATC automation design.

In the software area, advances have been made in software production practices and in the development of test and validation capabilities. The industry has recognized the need to bring the state of the art of software reliability to a state comparable with hardware reliability. In addition to formalizing practices for improving software development, automatic tools are being used for aiding both the development and validation processes. Appendix A discusses the software subject in more detail.

2.2 Ground/Air Communications

The Discrete Address Beacon System (DABS), which has been under development by the FAA for the past five years, has a ground/air/ground data link integrated into its operation. The DABS system will start to be implemented in the mid-1980's. When DABS is deployed on the ground and in some aircraft, the FAA will have for the first time a digital data link between the ground and aircraft that can be used for air traffic control (other data link systems might be needed for service outside DABS coverage areas and for exchange of other information). The digital data link is an important prerequisite for successful exploitation of ATC automation. It may be able to increase controller productivity by permitting direct digital communication from the ground automation system to the aircraft. Eliminating many of the human errors and misunderstandings involved in verbal communication is likely to improve safety. Voice communication, even if generated automatically could still be provided in parallel with the data link communications. Furthermore, if increased information on the traffic situation is needed in the cockpit to permit pilots to verify the safety and validity of computer generated clearances, then the data link could communicate such information to the cockpit.

DABS is an integral radar beacon surveillance and data link system. It has radar on the ground with surveillance and digital communication channels to an ATC facility, and a DABS transponder in the aircraft connected to other displays and devices in the aircraft. Since a DABS radar generally uses a rotating antenna, surveillance and data link communication take place when the antenna is pointing toward the aircraft. This will happen every 4 to 12 seconds depending on the FAA ground site's capability. Higher rates are possible if needed. The DABS data link is two-way. Data can be sent from the ground to the aircraft (the uplink) or from the aircraft to the ground (the downlink). Transmission data on the downlink can be either aircraft-initiated or requested by the ground. Data link

transactions are normally between the ground and a single aircraft. This is done with a 24-bit DABS address permanently and uniquely assigned to each DABS aircraft.

DABS provides a high quality link with several error-protection features. The uplink is protected by error-detecting encoding. If the error detection check is not successful in the transponder, the uplink message is rejected. Therefore, the probability of the transponder accepting a message addressed to another aircraft is near zero. Each uplink message elicits technical acknowledgment that the message was received and the error check was successful. If the technical acknowledgment is not received by the ground, additional attempts will be made to transmit the uplink message while the aircraft is still in the antenna beam. If the message is not successfully delivered during one scan of the antenna, DABS will continue to attempt delivery up to the time limit specified by the message originator. An indication of successful or unsuccessful delivery is provided, and forwarded to the originating ATC facility.

All downlink transmissions are protected by error-correcting encoding. DABS schedules the replies from all aircraft so that the replies from different aircraft will not overlap.

The DABS data link is a high data rate channel. The uplink operates at four megabits per second and the downlink operates at one megabit per second. The capacity of the DABS data link has been analyzed. A study showed that the DABS data link could supply data to every aircraft faster than a 110 baud teletype. This study was based on a model that represented the highest density of air traffic in 1995. It demonstrated that the DABS data link could support all required ATC data link services, including delivery of ATC clearances generated by a ground automation system, and also ground-generated information for displays of traffic in the cockpit (see Section 2.5).

Three engineering models of a DABS sensor have been procured by the FAA. The first has been delivered and is now being tested at the FAA's National Aviation Facilities Experimental Center (NAFEC). After engineering tests and evaluations, operational equipment could be bought and DABS could be in operation in the early 1980's.

2.3 Surveillance

The DABS system gives better radar beacon surveillance than today's Air Traffic Control Radar Beacon System (ATCRBS). DABS also provides a communication link for air-to-air surveillance

in regions outside of DABS ground coverage. All aircraft with ATCRBS transponders within its antenna beam respond to each ATCRBS interrogation. Replies from airplanes within a radar slant range of 1.65 nautical miles of each other will overlap. This condition is called synchronous garble. It can persist for many radar scans and often results in incorrect decoding of the ATCRBS Mode A or Mode C code, or loss of surveillance data. DABS interrogates each aircraft individually and schedules the interrogations so that the replies will be received without overlap. It eliminates the synchronous garble problem.

DABS addresses are permanently assigned to airframes so that when DABS is fully implemented Mode A beacon code changes are not required. Radar tracking is improved because each aircraft has a unique address. With ATCRBS, the tracking algorithm cannot always depend upon a unique code for report-to-track association, since not all aircraft are assigned discrete codes. DABS includes other extensive digital processing that provides benefits such as monopulse azimuth estimation and improved false target elimination.

The altitude and identity information transmitted from the DABS transponder is protected by error-correcting encoding. In ATCRBS, this data has no parity protection. The DABS system transmits the altitude replies received by the ground back to the aircraft for display to the pilot. This feature is called Altitude Echo. It can detect altitude encoding errors that will go unnoticed in the ATCRBS system.

DABS can net neighboring DABS sensors through direct sensor-to-sensor communication channels. With this capability, DABS sensors can transfer an aircraft from one sensor to another. Sensors can also exchange surveillance data with each other. When one sensor temporarily loses contact with an aircraft, another sensor can provide surveillance data. Sensors also recognize the failure of one sensor in the communications network. When this happens, the sensors adjust their service boundaries to cover the airspace served by the failed sensor.

2.4 Data Link Displays and Input Devices

Recent advances in technology have supported the evolution toward all-digital avionics in aircraft. Standard digital data bus structures for commercial aircraft have made it convenient and economically feasible to interface the data link terminal to the other avionics in the aircraft. This makes direct communications between a ground automation system and airborne computers possible. For example, a system can be envisioned in

which clearances could be generated automatically from the ground automation system, sent to the cockpit through DABS and, after the pilot's approval, sent directly to the navigation computer of the aircraft. The reverse is also possible. The pilot could ask the ground computer about a proposed flight plan change by entering the change on a cockpit keyboard or touch-entry display, send the message to the ground computer, receive the reply in the cockpit via DABS, and observe the answer on a cockpit display.

Technology has now made it quite feasible to incorporate cathode ray tube (CRT) displays with high quality graphics and alphanumerics capability in commercial aircraft. These displays are highly flexible and can be adapted for different phases of flight. Highly developed techniques could give the pilot quick and easy interactive capability with his data link and other onboard systems through menu-selection approaches. Improved brightness, contrast, and other human factors attributes of displays have made CRT's very suitable for airborne displays.

Multi-colored CRTs have been commercially developed and several flight-worthy programmable color CRTs are now being marketed for weather radar. Color can display more items on one screen without excessive clutter. For example, surrounding traffic, navigation information, significant terrain obstructions, minimum sector altitudes, and severe weather patterns might all be displayed simultaneously on a single horizontal map display. Color CRTs are feasible in higher performance general aviation aircraft as well as in large commercial aircraft. Multi-color weather radar displays with character-generation capability are now being marketed for general aviation aircraft.

In addition to CRTs, a wide range of devices are available which may be suitable for pilot interfacing with the data link. Paper printers can now be installed in the cockpit. Many types of keyboards and entry devices are available. Certain categories of data link information can now be presented in the cockpit with prerecorded or synthetically generated voice.

2.5 Cockpit Display of Traffic Information

One particular application of the displays described in the preceding section is for Cockpit Display of Traffic Information (CDTI). CDTI refers to the pictorial display of relevant traffic to the pilot. With CDTI, the pilot would be able to observe the current separation and with less accuracy the trend in separation between his own aircraft and another relevant aircraft. CDTI offers the pilot more information about the

traffic situation around him than is currently provided. With a new approach to aircraft separation assurance, the pilot might be given responsibility through use of CDTI to keep himself separated from other aircraft. Of course, such an approach would have to be validated via an appropriate test program.

The CDTI display could receive its information from the ground by the DABS data link or from an onboard surveillance system. A BCAS capable of determining the bearing of surrounding aircraft can support the display of traffic information in the cockpit. BCAS is a collision avoidance system that is wholly contained on the aircraft. It can observe other aircraft in its vicinity that have an ATCRBS or DABS transponder, although there are serious questions as to whether any BCAS will see ATCRBS equipped aircraft well enough to support all CDTI functions. Several different BCAS devices with different capabilities have been proposed. Depending upon how bearing information is determined, a BCAS might be able to support a CDTI display in areas outside of DABS surveillance.

2.6 Navigation Systems

The world-wide civil en route navigation standard is the VOR/DME. The ATC system routes are based upon this standard. The standard route structure is a network of fixed point-to-point segments. Guidance is provided by fixed radial course-lines emitted from the VOR ground stations. The DME provides distance from the ground station. Area navigation (RNAV) systems allow the pilot to fly any desired course if the aircraft is within station coverage.

RNAV operation can be divided into three categories; 2D, 3D and 4D. The basic capability for flight over any desired horizontal course is provided by 2D RNAV. A significant benefit of 2D RNAV is that it permits direct-to-destination routes. It also provides onboard guidance which can replace terminal area radar vectoring procedures. RNAV provides guidance for non-precision approaches to runways without this capability.

Vertical guidance through the derivation of ground referenced flight path angle is given by 3D RNAV. This enables equipped aircraft to fly arbitrary flight paths defined by both horizontal and vertical coordinates. The main advantages of 3D RNAV are that it provides vertical guidance during fuel conservative approaches, it provides the capability for a glide slope-like approach on non-precision approaches, and it enables the ground system to rely on better adherence of the aircraft to its flight plan.

The third category, 4D RNAV permits onboard information for delivering the aircraft precisely to a waypoint within narrow time and speed limits. Exploiting the advantages of 4D depends on changing the ATC system so that it is built around this capability, and would require this capability to be installed on most aircraft. If this were done, the automated ATC system could be simplified because it could issue pilots complete 4D clearances to assure separation. These clearances might cover long periods of flight (e.g., 30 minutes) and the ground system would then have to play only a monitoring role. Even within the context of today's ATC procedures, 4D navigation could be used as a backup coasting capability if an automated ATC system fails.

RNAV systems may be based either on radio navigation or on self-contained navigation systems such as Inertial Navigation. RNAV radio navigation systems today use VOR/DME or VLF/Omega. Until the advent of light-weight and inexpensive digital computers, the RNAV radio navigation concept could not be applied on a large scale. One of the largest avionic manufacturers recently announced an integrated VOR/DME/RNAV set for about $5000. More than 10,000 RNAV sets are in use today, because of the cost/benefit advantages of RNAV.

There are only two certified 3D RNAV sets on the market since the establishment of the 1975 FAA certification criterion. There are no full capability 4D systems commercially available. However, most RNAV sets give a readout of time-to-go to waypoint. A fully capable 4D RNAV would include the automatic computation of airspeed commands to meet a time objective, and would be integrated with the flight control system. The FAA is currently testing a system containing these features.

Since the cost of digital electronics and interfaces is coming down rapidly, the general aviation market for RNAV will increase. In addition, U.S. air carriers may renew their interest with the next generation of aircraft since they could economically integrate the RNAV into the Flight Management System.

3. AUTOMATION ISSUES

Automation makes improvements in the ATC system possible. The technology to achieve this automation already exists and is continuously improving. However, advanced automation concepts must evolve from today's system. This raises several important issues, some related to the evolution of the roles of the government, the air traffic controller and the pilot, and others related to the evolution of airborne and ground based equipment. This section discusses some of the key issues which the Automation/Productivity Group dealt with.

3.1 Ground System ATC Responsibilities

Today, the ground system provides pilots participating in the ATC system with flight clearances to assure separation. The ground system attempts to manage traffic flows evenly and equitably distribute necessary delays among aircraft. Under visual conditions, the ground system can transfer certain separation responsibilities to the pilot, such as following the aircraft ahead during the final approach to an airport.

The ground also performs a flight following function using ground-based surveillance systems, on a workload permitting basis. This ensures safety, permits closer aircraft separation, expedites traffic, and allows the ground to react to any unusual circumstances or unexpected events.

Under certain circumstances the ground system will also navigate aircraft with radar based vector instructions.

Three concepts for the future ATC system were addressed by the group and are discussed in detail in Section 4. Each of these concepts provides mechanisms for reducing the ground system's navigation responsibilities. The concepts differ in their allocation of current ground system responsibilities within the functions of separation, flow management and monitoring. The concepts coincide on the following important system responsibilities, which the group believes are basic

(1) ATC clearance generation should continue to be a ground system function since it alone has the necessary information to carry out this function.

(2) ATC clearance execution should continue to be an airborne function. Hence, automatic coupling of aircraft flight control from the ground is not a desired automation capability.

Depending on the results of future E&D activities, clearances may delegate more separation responsibilities to the pilot. This subject is discussed in more depth in Section 4.

3.2 ATC-Related Roles of Pilot, Controller and Computers

Several alternative concepts for how pilot, controller and computer roles might be changed were dealt with. Major improvements in the ATC system and increased productivity mean that the current ATC-related roles of the pilot, controller and computer must evolve in different ways. The considered alternatives were:

(1) Keeping current pilot roles relatively constant, but shifting certain functions from the air traffic controller to the computer, and giving the controller some new roles.

(2) Shifting certain flight following and monitoring roles from the air traffic controller to the pilot, with the help of computer and data link, in addition to shifting certain controller roles to the computer.

(3) Shifting certain separation related roles from the air traffic controller to the pilot, with the help of the computer and data link, in addition to shifting certain controller roles to the computer.

Some important agreements were reached by the group. Since significant alterations in the functions of the pilot will probably require new airborne equipment, they must be approached gradually. There may never be a complete change in this direction because of the expense of the airborne equipment and the training of pilots needed to use the equipment. Thus, whatever automation capability is developed must take into account the limitations of those pilots whose functions in ATC will remain constant. Future automation will transfer certain controller roles to the computer. As a result, changing controller roles should be the basic approach to automation, and capabilities which permit new pilot roles should be augmentations of the basic approach.

More specific discussion on the controller and pilot roles is presented in Section 4.

3.3 Avionics Requirements

An examination of avionics requirements raises the question of the minimum avionics necessary on-board aircraft to achieve

future productivity objectives. There is also a question of how to deal with ATC automation concepts which require almost all aircraft to be equipped with new avionics. Some important principles were established by the group.

(1) The government should not expect users to purchase new avionics which will only reduce ground system operating costs. The user should receive tangible benefits including suitable return on investment from any new avionics he or she purchases, and purchase should be voluntary.

(2) Significant numbers of aircraft are currently equipped with transponders and altitude encoders. For safety reasons this equipment is currently required in certain airspaces. The automation system must produce obvious benefits in airspaces which have the minimum avionics requirement of transponder, altitude encoder, VOR navigation and two-way radio.

(3) ATC concepts which provide additional capabilities and benefits for additionally equipped aircraft, regardless of quantity, are preferred. Concepts which provide no additional capability until most aircraft are equipped should not be seriously pursued.

The group believes that, of all the additional airborne capabilities, data link may ultimately achieve the most productivity benefits. Therefore, the FAA should encourage data link by providing, in addition to automatic communication of ATC clearances, a wide range of additional benefits to users carrying this equipment. For example, in-flight weather information could be provided. The timing of the availability for such data link services must be related to when and where the ATC system can extract its desired productivity and safety benefits.

3.4 Services to Voluntarily Equipped Aircraft

As was discussed in Section 1, the group believes that the future system must be more flexible. It must be more capable than today's system to benefit users with additional airborne capabilities, which promise either immediate or eventual system wide benefits, even if these users should be in the minority. Data link is the key avionics system for increasing productivity. Beneficial data link services should be developed to be available for implementation in a common time frame with advanced ATC automation systems to encourage acquisition of airborne equipment.

While the ATC system and its associated automation should be designed so that advanced airborne capabilities can be exploited, it should not require the advanced capabilities in order to function.

3.5 Hardware Failures and Backup Systems

The issues here relate to the objective, raised in Section 1, of increasing user confidence in advanced automation. The expanding use of automation to increase system productivity will result in automation systems assuming greater responsibility to provide the same or better capabilities with more reliability than the human controller provides in the current ATC system. People do not forgive a machine's failure. This human perspective requires increased emphasis on the design of reliable hardware systems. As indicated in Section 1, the current en route and terminal systems have very limited backup modes. With the changes in computer technology discussed previously, cost-effective redundant computer configurations which would be much more effective than the current backup capabilities become feasible. The more recent DABS developments have resulted from the great attention paid to hardware failure. Its computer architecture includes a comparison procedure, in which sets of paired computers with specific computation functions agree on their computed outputs, or the pair is automatically replaced.

Reliability is also enhanced when the simultaneous failure of certain functions is avoided by making them as independent as possible. The FAA plan is to locate its Automated Traffic Advisory and Resolution Service (ATARS) at the DABS site to provide a continuous back up service in the case of a major ATC failure. DABS sites can be interconnected to monitor failures in a neighboring site and assume the surveillance, communications and ATARS functions in the overlapping areas of coverage in case of such failure. Similar approaches should be investigated within the automation system. For example, a single center's automation system can consist of several interconnected modules, each providing automation within a limited airspace. If a given module fails, adjoining modules in the same facility are able to assume the functions of the failed module.

Even though the group believes significant emphasis should be placed on hardware reliability, it also recognizes that failures will occur and that adequate backup mechanisms must exist. This subject is further developed in Section 4.

3.6 Software Verification and Error Recovery

Software (computer programs) has become the largest single cost item in many current automation systems. The cost of computers and other hardware components has dramatically decreased. In large automation systems, such as the Air Traffic Control systems, software is particularly costly because of the large amount of support required. Processes for development of quality software with minimal errors have not yet been perfected. They are the subject of study and considerable discussion in the literature.

Successful software efforts are caused by many factors including consistent application of good standards and practices, availability of good design tools, awareness of other developments in the field, and existence of effective software acquisition management. Successful efforts are also heavily dependent on the knowledge and experience of key personnel in both the customer and program development organizations.

It has been shown[4] that a combination of factors ensure a successful software acquisition effort. Good tools without effective management are not effective, nor is effective management without good tools. The referenced study also observed that the quality of early plans, system definition, including consideration of all life cycle factors, significantly effects the quality and reliability of software in later stages of development and application. Errors are most easily resolved early in the process.

An early effort is needed by the FAA to define the standards and practices to be used to develop software, to ensure effective software acquisition management for in-house and contracted efforts, and to encourage development of improved software development tools and techniques. Appendix E discusses the software development tools and techniques in more depth.

No matter what design precautions are taken, software errors will occur. Backup mechanisms must be developed in the overall system for safe recovery from such situtions. This subject is dealt with further in Section 4.

3.7 Use of Ground Derived or Air Derived Data

The group discussed the importance of the source of particular data. It is possible by data link to provide aircraft with information from the ground. Airborne sensors may also be used. Some important points came out of these discussions.

(1) More important than the source of data is having the data at all. The source of data is not such an important requirement that it should dictate and possibly hinder the possibility of information available to an aircraft.

(2) The use of air derived traffic data as the basis for pilot's double-checking the ground system has the attraction of independence. However, independence would have obvious disadvantages if the information was used to coordinate distribution of traffic control responsibilities between air and ground, since each party may not know of the existence, accuracy and currency of the data being used by the other party.

In obtaining traffic data on-board aircraft, both air and ground sources are technical possibilities. It is necessary to decide the purpose for the traffic data before committing to an air or a ground source. For example, in cases of close separation, such as close parallel flight en route,, a higher data rate and greater relative accuracy than can be achieved from the current en route surveillance system may be desirable.

3.8 Human Factors

Controller and pilot human limitations and strengths should dictate the advanced system designs. This aspect of system design is so critical that it can dictate the extent that automation is possible. It can alter the distribution of responsibilities between pilots and controllers. In view of this importance, concepts for automation must consider human issues early in their development. These must consider the pilot and the air traffic controller. Human factors for both pilot and air traffic controller must be dealt with experimentally using real-time simulation, and when possible live testing. The people who are to operate and use the automation system must be given meaningful roles with sufficient workload implications, to assure both their attention and interest. In the past, beneficial automatic designs for aiding air traffic controllers have been accomplished by FAA with relative ease because almost any degree or kind of automation could increase human productivity. However, in development of significantly greater applications of automatic devices and techniques, well defined descriptions of what the controller or pilot should actually be trying to accomplish are not immediately obvious. Such descriptions are sometimes virtually impossible to deduce without research. Further, the system can unknowingly encroach on the operator's interpretation of his functions and prerogatives. For example, some potential

problems can result when the controller removes himself from the actual control process and becomes dependent on an automation system's operation, and vulnerable to the consequences of system failure or poor system design; or the human can rebel and refuse to accept some part of his new function. He can indeed, even intercede with a process, however accurate and correct, if it doesn't function as he would. A further problem is related to a system design that does its function without any need for intervention. In this case the controller is not a systems operator, but a monitor; a task humans do poorly. The operator in this situation is likely to fail to monitor, or may unnecessarily interfere to alleviate his boredom.

A rational and viable alternative to forcing a man to live with an unacceptable automatic system is to take full advantage of man's attributes, i.e., assessment and judgment, in the automation design process. The group believes that the automation design and the human factors are so tightly related that human factors must be an integral part of the automation design and development efforts.

The human factors activities should include efforts which deal with methods for transitioning human roles. Satisfactory methods of introducing automatic communications and computer decision making are crucial to achieving the desired goal of automation. Within, and central to, each of its automation activities which involve changing human roles, E&D should have adequate experimental programs looking into the relevant human factors issues.

3.9 Automation Related Maintenance

FAA has a substantial number of employees involved in the maintenance of remote electronic facilities. The productivity of these maintenance people is limited because of the quantity of preventive maintenance required by much of the current FAA equipment, and the necessary travel time to get to the geographically distributed locations of these facilities. Techniques have been demonstrated where facility performance is monitored remotely at a central location; diagnostics are also performed at the central location using modest levels of automation. In addition technology provides many opportunities to design equipment with fail safe/fail soft characteristics which in conjunction with remote monitoring and diagnostics has the potential to dramatically reduce requirements for on-site preventive maintenance and repair. As a result, substantial maintenance savings appear to be possible. In order to curtail the growth of maintenance manpower, and to reduce costs of maintenance, it would appear that such remote maintenance

techniques should be investigated further. In addition, savings would appear possible at larger FAA sites through use of improved equipment design and diagnostics.

3.10 Transition to Advanced Capabilities

The issue of concern here is how to get from where the ATC system is today, to a more advanced automation system. This involves mechanisms for gradually changing ground system responsibilities, human roles, hardware and software.

The evaluation of human roles is believed to be an important issue, and it has been dealt with already in Section 3.8. Another set of questions arise in terms of ground system hardware and software transition. The current computer systems (9020, ARTS III, ARTS II) do not have sufficient capacity to incorporate major new functions. These systems include some computing functions which would continue to be useful in a more advanced systems, (e.g., flight plan processing) and some which might not (e.g., en route primary radar aircraft tracking). The question here is how to best build upon the investment which already exists in these systems, without seriously inhibiting the design of the future hardware and software systems.

The group is concerned about new capabilities being added to the existing automation systems before hardware replacements are made. The transition path for replacing existing hardware and software must include the ability to add new functions to existing automation during the long process for replacement. Of course, the replacement of existing functions requires significant validation. This validation process could become a very large problem, particularly with the software, if the replacement is made in a single step.

In view of these factors, the plans for replacement of existing automation hardware and software:

(1) to avoid the potential for major software validation problems, should not include a large changeover in a single step

(2) should not stop additional functions from being added to the existing system, while waiting for the replacement, and

(3) should result in a system designed for continuing evolution.

It appears as if a technical means for accomplishing these requirements exists, via the use of distributed processing. See Appendix A for a discussion of advantages and disadvantages associated with the use of distributed processing. Distributed processing concepts, if properly planned, can permit gradual step by step upgrades to the existing system which are compatible with the eventual system in hardware and software. Such concepts should be given strong consideration by the FAA in addressing their hardware and software replacement programs.

3.11 Role of Primary Radar in the En Route System

Primary radar provides two functions in today's en route ATC system: aircraft tracking and weather detection and mapping. Present radar systems are designed for aircraft tracking. They are not optimized for weather detection. The aircraft tracking capability provides a backup to beacon failures, and surveillance on aircraft which are not equipped with transponders.

In the past, the system was needed for primary radar aircraft tracking more than weather detection. However, because new regulations require more aircraft to carry transponders the need for primary radar-based aircraft tracking capability has diminished. Furthermore, with greater dependence on aviation in all weather conditions, the need for weather information has increased to where the group believes that weather detection is needed more than aircraft tracking by primary radar. The group believes that the major role primary radar may play in today's en route system is to track weather rather than aircraft, even though it is not appropriately designed for this purpose. Appendix F presents some data which indicates how little the IFR system currently relies on primary radar aircraft tracking.

Secondary radar rather than primary radar is the basic aircraft surveillance tool, in today's system. This will continue with an advanced automated system. With the continuing improvements in beacon surveillance (e.g., DABS) the automation system can operate without using primary radar for aircraft tracking. The data in Appendix F indicates that this is virtually true already in today's en route automation system. However, in certain coastal situations primary radar would still be required.

If the en route automation is to automatically provide clearances which avoid sending aircraft through severe weather areas, it must have a reliable and continuous source of weather data. Without such a source, the automation system could only reroute aircraft around specific airspace areas which the traffic controller presented to the computer manually.

Therefore, the FAA's direction in en route primary radar development should be towards weather detection and mapping capability, rather than aircraft tracking capability.

In addition to potential safety implications, other important issues are raised by this change in emphasis. Most of the current en route primary radar system is old. It requires a high degree of maintenance and must be replaced shortly. The group believes that any replacement must provide improved weather capability, even if this delays replacing the system.

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4. CONCEPTS

This section discusses alternative ATC concepts and the automation support needed to achieve the objectives of Section 1. It also relates the group's findings on issues discussed in Section 3 to these alternatives to establish a desired automation approach.

4.1 ATC Concepts

Three ATC concepts were discussed by the group in depth. Two of these are concepts developed within FAA's E&D activities. These are Automated En Route Air Traffic Control (AERA) and Strategic Control. Appendices B and C discuss these concepts in detail. The third, the Pilot-Based ATC Concept, was formulated by a subgroup of the Automation/Productivity group. It is presented in detail in Appendix D.

Figure 1 is a generic block diagram of the ATC system. This shows the ATC system divided into four essential parts:

(1) the separation function consisting of

- (a) conflict prediction,
- (b) conflict resolution,
- (c) clearance formatting into terms the pilot can understand,
- (d) communication of clearances to the pilot and
- (e) execution of clearances by the pilot.

(2) the flow management function which

- (a) expedites traffic when possible
- (b) determines when demand exceeds capacity,
- (c) sequences traffic, and
- (d) equitably distributes delays among aircraft and assigns holding patterns.

(3) the monitoring function based on radar surveillance

- (a) monitors aircraft positions, and
- (b) makes clearance changes when needed

(4) the pilot request function with two paths for pilot input

- (a) preflight inputs via a flight plan, and
- (b) requests for changes via air to ground communication.

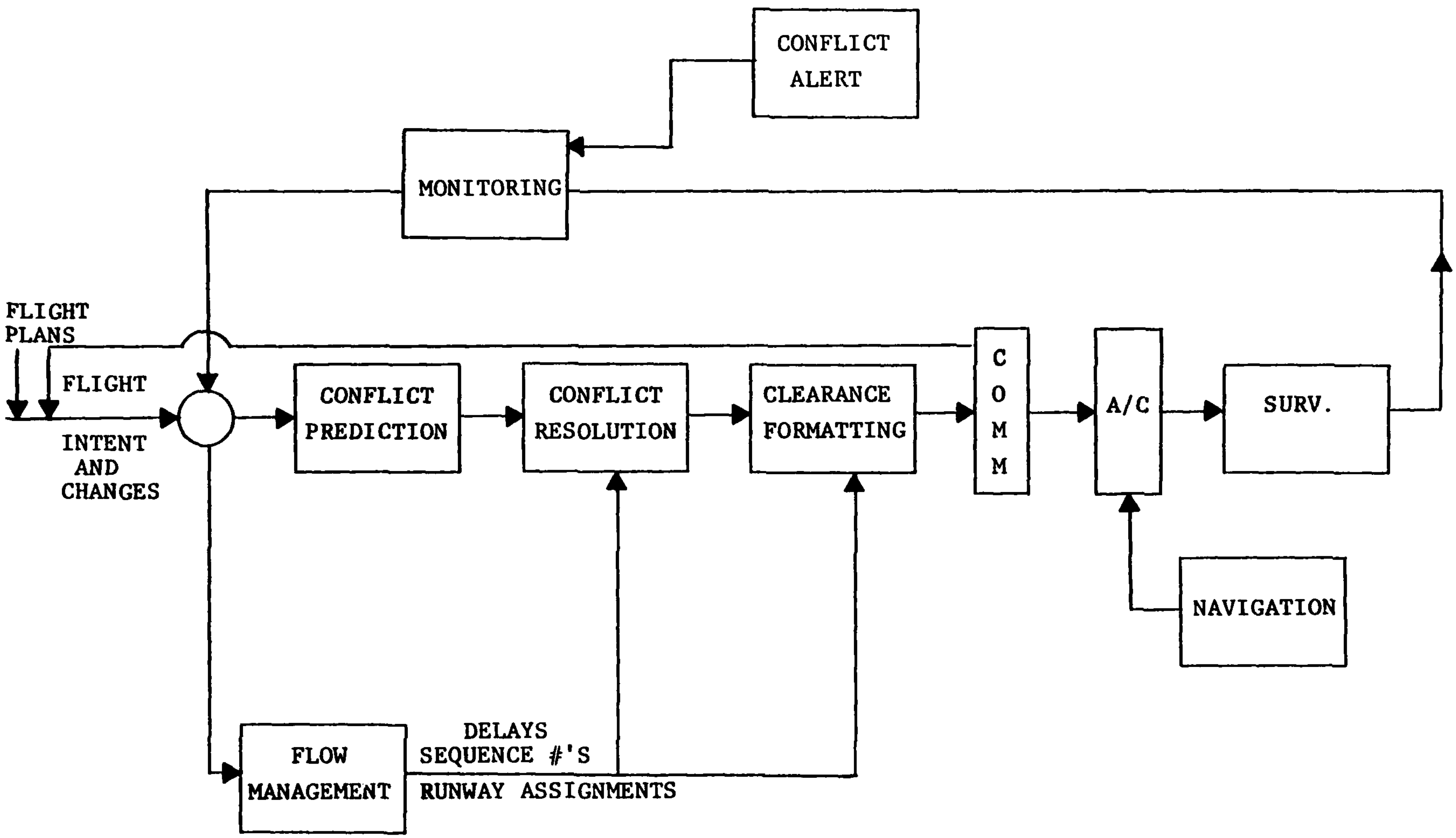


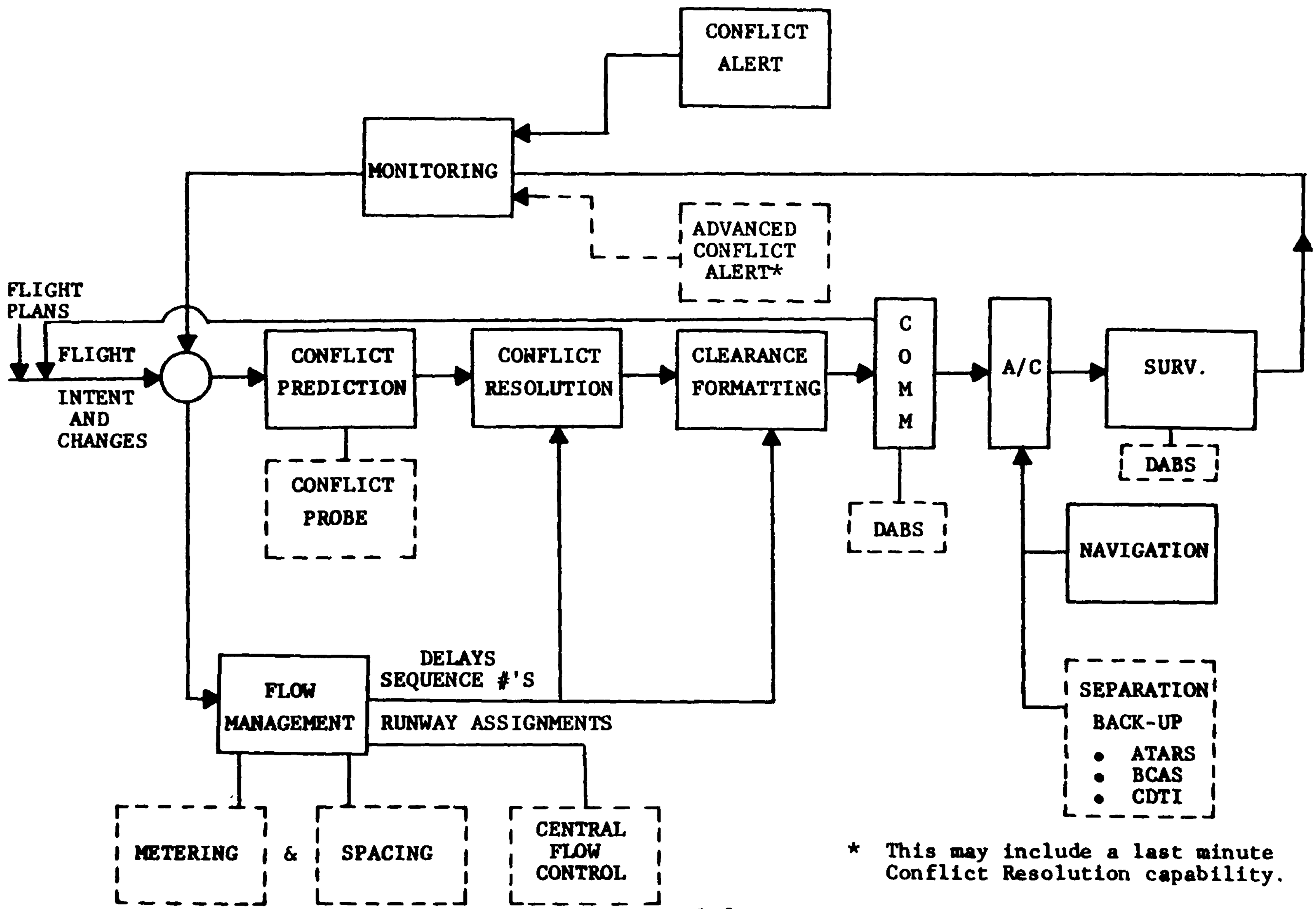
FIGURE 1
ATC FUNCTIONS

In today's system the air traffic controller manually performs all the non-aircraft ATC functions in Figure 1. The computer provides some radar and flight plan data and the Conflict Alert System provides automatic aid for monitoring. Voice radio is the means for communication. The FAA is now working on several near-term programs which could automate individual parts of this process. Figure 2 shows these programs in dashed boxes, and how they relate to the basic ATC process. The generic Conflict Resolution Function is not being developed as a near term function. However, the three ATC concepts discussed in this section deal with automating all of the functions, including Conflict Resolution, as the means for achieving the maximum productivity benefits. While the three ATC concepts are similar in the degree of automation which is needed to support them, they differ in how they distribute the responsibility for the functions in Figure 1 between ground and air.

AERA (Automated En Route ATC)

AERA is an en route ATC concept for high altitude and high to low altitude transition airspace. See Appendix B for details. It potentially achieves increased controller productivity by providing the controller with an automatic clearance generation capability and automatic ground to air communication capability via data link. These features combined make it possible for pilots to receive their ATC clearances directly from the automation system being supervised by an air traffic controller. The automation system combines the separation and flow management functions, does its own monitoring, and aids the ATC supervisor to monitor the system. In AERA, responsibilities are divided between ground and air the same way as in today's system. The basic AERA system requires aircraft to be equipped with two-way radio, VOR navigation, transponder and altitude encoder. However, the full productivity benefits of AERA will not be achieved until a large percentage of aircraft are carrying a data link receiver. While functional responsibilities are not changed, more use of automation potentially provides the necessary reduction in controller coordination workload and controller flight monitoring workload, so that greater flexibility in airspace utilization can be achieved and improved services can be provided to voluntarily equipped aircraft.

AERA also continuously updates up to a 20 minute plan for each aircraft's flight. This saves fuel by scheduling necessary delays while the aircraft is in a clean configuration. It also gives the air traffic controller advanced notice of plans. This same information could potentially be sent to the pilot as well.



* This may include a last minute Conflict Resolution capability.

FIGURE 2

FAA AUTOMATION PROGRAMS RELATED TO FUNCTIONS

Some key issues related to AERA are the ability to develop a satisfactory role for the air traffic controller (Section 3.8) and the development of an overall system design which provides users with confidence in such a high level of automation (Section 4.2).

Strategic Control

Strategic Control is a high density terminal area ATC concept. See Appendix C for details. It can achieve increased airport capacity by precisely spacing aircraft at the runway. Precise spacing depends on aircraft equipped with 4D navigation systems (see Section 2.6) so that they can arrive at a destination within 5 seconds of a planned time. The ground system provides an automatic separation and flow management planning function. This gives 4D route profiles for each aircraft considering their aerodynamic capability. These profiles assure separation and maximize flow. They extend about 150 nmi, so that, once cleared to fly, the pilot would not normally be disturbed by ATC for a reasonably long time. In order for the system to work at maximum effectiveness, it depends on great precision in flying the profiles. This is where the 4D navigation is used.

In addition to deriving 4D profile clearances for pilots, the ground system also provides an automatic flight following function via ground-based surveillance. This monitoring detects deviations from the desired profiles, and provides guidance to pilots if required. If an aircraft deviates a large amount and cannot be returned to its profile, the system would automatically recompute the profiles of other aircraft to accommodate the deviation. With the Strategic Control Concept, the split of ground and air functional responsibilities is somewhat changed from today's system and the AERA concept. The change is to transfer accommodation of aircraft 4D flight profile variations from being a ground responsibility to being an airborne responsibility. Flight variations may be induced by either the aircraft itself or due to uncertainties in the environment (e.g., unpredicted winds). This transfer would be accomplished by the ground system using time as the means for planning separation and flows, and 4D navigation clearances as the means for accomplishing the desired times. By transfering this responsibility from ground to air, certain controller productivity benefits may become possible.

The group is concerned about how one evolves to the Strategic Control Concept. Since the concept depends on aircraft carrying 4D navigation equipment, one must depend on benefits to the early user encouraging a larger number of operators to equip.

It is not yet clear whether or not enough early user benefits exist for 4D navigation. Another concern in utilization of a Strategic Control concept is that care be taken to insure that operating flexibility is not lost due to unnecessarily long 4D navigation clearances. Furthermore, 4-D clearances covering long periods of flight might produce speed requirements which are unacceptable in terms of economic flight performance.

Pilot-Based ATC

Pilot-Based ATC was developed by a sub-group of the Automation/Productivity Group. See Appendix D for details. Pilot-Based ATC provides greater pilot involvement in the ATC process and yet it is based on, and is consistent with, the current ATC system. Current ATC services, or an AERA automation system, are augmented with a special set of beneficial clearances which are given to operators who purchase special avionics, and who choose to take greater ATC responsibility for their own aircraft. These special clearances are referred to as traffic-based clearances. When issued by the ground, they turn over the resolution of a specific traffic conflict to the pilot of an aircraft equipped with an Integrated Traffic and ATC Information Display. This display provides the pilot with radar-measured locations of traffic and information on that traffic's intent, so that he or she is able to maneuver to avoid a conflict. This capability might permit pilots to improve their flight's efficiency and provide more freedom of the airspace. It is recognized that the conflicts for which Pilot-Based ATC is viable are limited. As a result, traffic-based clearances are limited in use to situations with only one conflict and where no third aircraft is in the vicinity, so that the pilot's maneuver cannot cause a new conflict.

Pilot-Based ATC enables the pilot to independently validate his ATC clearances by using his Integrated Traffic and ATC Information Display. If the pilot receives a clearance which does not seem to be safe or appropriate, he or she can ask the ground system to recheck it and, if necessary, issue a new clearance. As the number of aircraft with Integrated Traffic and ATC Information Displays increases, increased controller productivity becomes possible because of the shift of responsibilities to pilots. The concept which initially only benefits the owner of the necessary equipment evolves to one which has overall system benefits.

With Pilot-Based ATC the delegation of ground and air functional responsibilities is somewhat changed from today's system and the AERA concept. In certain situations the separation function is assigned to the pilot. The ground system is responsible for detecting all traffic conflicts, and isolating those which can use traffic-based clearances. After issuing a clearance to the pilot, the ground system transfers the separation function to the cockpit. A second change in functional responsibilities is in the monitoring function. In today's system the pilot's responsibilities are limited to visual sighting of aircraft. With Pilot-Based ATC the pilot and the ground system both have radar-based monitoring responsibilities. These changes in functional responsibility may be able to operate within a system which is still using the current delegation of responsibilities for all unequipped aircraft. This makes such a concept attractive.

Several issues related to the Pilot-Based ATC Concept were raised by the group. These included concerns about the safety of the ATC procedures, since situations of delegated control would become more frequent (divided between ground and air), and would involve handoffs of responsibility from ground to air and back to the ground. Human factors issues were also raised, including questions about the air crew's ability to carry out the separation tasks while performing normal duties with expected proficiency, and the air traffic controller's ability to control traffic within a delegated responsibility set-up. Also of concern is the reduction in flight crew productivity which would result if the implementation of the concept requires an additional air crew member.

The group raised concerns about the degree of redundant DABS ground station coverage which this concept might require, since with the loss of a DABS site an aircraft could lose its traffic information, ATC data link messages, and ground-based collision avoidance capability, while carrying out a traffic-based clearance. This led to the feeling that either an independent airborne collision avoidance system would be needed on-board participating aircraft, or a high degree of redundant DABS ground station coverage would be needed.

The three concepts each have many desirable features and seem technically feasible. They are interesting candidates for the future ATC system. The group discussed and evaluated these concepts and, as a result developed a set of desired design requirements for future, more automated ATC systems. These requirements are presented in Section 5.1. Furthermore, the group developed some specific recommendations for E&D activities which appear in Section 5.2.

4.2 Concepts for Increasing User Confidence in Automation

The group recognized the need for user confidence in automation as such a key factor that it has become a primary objective. The group developed some methods for achieving such confidence.

The group looked at today's NAS automation and found that more reliability is needed. The computer architecture and software development and validation for the ground system must be designed for very high reliability. Technical discussions presented in Appendix A and Appendix E indicate that such a requirement is technically achieveable.

Several steps are required beyond pursuing a reliable computer hardware and software capability to achieve the necessary confidence. Pilots and controllers must be confident that the outputs of the automation system are correct, but they must also know that, when the rare error is made, they have mechanisms to deal with it. They must be confident that the automation system will not suddenly cease to operate, and they must know about alternative systems in case of malfunction.

Automation should be designed with several tiers of responsibilities. The automation system, the air traffic controller, and the pilot each have well-defined functions under normal conditions. If the ground system automation fails, the air traffic controller should be able to continue with a backup operation. The backup capabilities should be as independent as possible of the main automation system. The backup system operation may not be as efficient as the normal one, but it should be as safe.

In the event of a more complete ground automation system breakdown, for example, of an entire traffic control center, adjoining centers should be able to take over backup control. This backup control may also be less efficient than normal operations, but should be as safe. Finally, the system should be able to shift certain backup responsibilities to the pilot. The pilot should be able to monitor collision avoidance equipment or traffic presentation systems in the cockpit which would insure the safety of the aircraft immediately after the failure. Several specific ideas for providing these tiers of responsibility are recommended in Section 5.

5. RECOMMENDATIONS

The Automation/Productivity Group recommended a set of design requirements and automation concepts for ATC, and a specific set of FAA activities. The two sets of recommendations are discussed below.

5.1 Design Requirements for Automation

This section integrates the design requirements discussed in previous sections as the basis for the E&D programs recommended in Section 5.2. These requirements are important not only within the framework of concepts discussed in this paper, but should be applicable to almost any ATC automation concept which the FAA pursues.

(1) Advanced automation concepts must evolve from today's system, and therefore must evolve from current ground and air responsibilities, current pilot/controller roles and current aircraft avionics equipage (including transponder and encoder) and the current ATC ground equipment. However, based on considerations other than evolution:

(a) ATC clearance generation should continue to be a ground system function since it alone has the necessary information to carry out this function.

(b) ATC clearance execution should continue to be an airborne function. Hence, automatic coupling of aircraft flight control from the ground is not a desired automation capability.

Depending on the result of future E&D activities, clearances may delegate more separation responsibilities to the pilot.

(2) If feasible, the future ATC system should provide automatic clearance generation and communication primarily via data link. This is not to imply that voice communication, whether manual or automatic, should not exist as well. The continued use of voice has two purposes. First, aircraft which are not equipped with data link equipment must be communicated with via voice. Second, voice communication should be continued until the safety implications of removing the resulting party line information are well understood.

(a) The automated system should use flight intent and weather information for planning, and secondary radar for surveillance (DABS or ATCRBS).

(b) The system should provide a flow management function including automatic

- sequencing of traffic.
- expediting of traffic.
- assigning of holding patterns, when necessary.

(c) The primary separation function provided by ATC should be automated and include use of aircraft overall flight intent.

(d) The system should deal with the interrelationships between the separation and flow management functions.

(e) The system should provide for greater pilot involvement in separation and flow management processes where such proves desirable by

- being capable of communicating, via data link, pertinent information to aircraft equipped to receive and present such information to the pilot,

- delegating via specific clearances, selected separation responsibilities to pilots.

(f) The system should manage adjoining airspaces so that boundaries are transparent, to permit more random routing and fewer altitude and route restrictions.

(3) The future ATC system should plan more precisely and over a longer time horizon than it does now, so that:

(a) air traffic controllers and pilots working with automation can know about developing traffic and congestion situations in advance.

(b) fuel can be saved by scheduling needed delays while the aircraft is either on the ground or at a fuel efficient altitude and in a clean configuration.

(c) there is improved continuity in the planning process. No changes in plan should be made simply because an aircraft has flown from the jurisdiction of the en route system to the terminal system, or from one air traffic controller's airspace to another's.

(d) controllers can be aided by automatic early recognition of situations which will require coordination action. Additional automatic mechanisms to help controller coordination should be provided.

(4) The future system must be designed to minimize the potential for air and ground system failures, resulting from hardware, software and human errors. However it is recognized that this potential will always exist, so that sufficient backup must be designed into the ATC system.

(5) The plans for replacement of existing automation hardware and software:

(a) to avoid the potential for major software validation problems, should not include a large changeover in a single step (e.g., the complete current 9020 software).

(b) should not stop additional functions from being added to the existing system, while waiting for the replacement, and

(c) should result in a system designed for continuing evolution.

It appears as if a technical means for accomplishing these requirements exists, via the use of distributed processing. Distributed processing concepts, if properly planned, can permit upgrades to the existing system which are compatible with the eventual system in hardware and software. Near term ATC capacity for supporting additional functions may be obtained by offloading certain existing tasks from the central computer to auxiliary processors. For example, offloading of some surveillance processing functions to computers at DABS sites.

(6) The automation system should be designed so that it provides benefits to IFR flights carrying transponder and altitude encoder, VOR navigation, and two-way radio. Automation concepts that provide additional capability and benefits for aircraft with more than this equipment should

do so, regardless of their number. Automation concepts which provide no additional capability until almost all aircraft have more equipment should not be seriously pursued.

(7) Of all additional airborne capabilities considered by the group, data link seems to be the most important element for increasing productivity. Therefore, data link acquisition should be encouraged by giving a wide range of additional benefits to users carrying this equipment.

(8) DABS is the desired data link system. Other data link systems might be needed for service outside of DABS coverage areas and for exchange of other information.

(9) The future automation system must be capable of providing benefits to users with additional airborne capabilities which promise either immediate or eventual system wide benefits, even if these users should be in the minority. While the ATC system and its associated automation should be designed so that such advanced airborne capabilities can be exploited, it should not require these advanced capabilities in order to function.

(10) The role of primary radar in the en route automation system should be directed toward providing weather detection and mapping capability, instead of aircraft tracking capability. This should not eliminate the use of non-radar procedural separation, nor the use of primary radar for tracking aircraft in special locations. The automation system should be capable of operating with secondary radar as its source of aircraft position surveillance, and should be capable of providing clearances which avoid severe weather areas as detected by the weather radar systems, ground or airborne.

5.2 Recommended E and D Activities

This section outlines a set of recommendations derived from prior discussions including the design requirements of Section 5.1.

(1) To achieve significant increases in controller productivity, the FAA should pursue a degree of automation significantly higher than that which now exists. The design requirements suggest the evolutionary development of an automated system. The system should initially include an AERA-like concept (Automated En Route Air Traffic

Control). The later introduction of Strategic Control and Pilot-based ATC concepts could prove desirable. Of course, these latter two concepts would require participants to carry associated avionics. The basic AERA concept may not require sophisticated avionics, although a data link would be required to achieve full benefits. User confidence in an automated system is crucial to its acceptance. In order to permit more effective use of the basic automated system and instil confidence in computer generated clearances, some operators may voluntarily equip themselves with more sophisticated avionics, such as 4D navigation, CDTI, BCAS and other avionics.

The FAA's en route ATC automation E&D program should attempt to design, develop, and demonstrate the feasibility and benefits of an AERA-like automatic clearance generation and communication capability, based on the design requirements of Section 5.1. Sizable goals, such as doubling the controller's productivity, should be established for this automation.

(2) The high density terminal area development objectives should be to provide automated aids to the air traffic controller's metering, sequencing and spacing function. Automation could also permit pilots to perform the final spacing function in instrument weather conditions. The group believes, however, that the development of more terminal automation than this should be dependent on E&D studies and results from the en route and terminal efforts recommended above.

(3) Pilot and controller confidence in automation is crucial for automation to benefit productivity. The E&D program must deal with the identification and development of failure protection and backup capabilities which will provide the integrity necessary to develop confidence in high levels of automation. This program should apply to terminal and en route and should provide ground system hardware and software design concepts which are an order of magnitude more reliable than today's system. Design standardization of terminal and en route systems should be considered. That is, use of standard system architectures, computer languages, software testing and validation procedures, and data bases may all be instrumental in upgrading FAA's ability to develop and maintain terminal and en route software.

This effort must establish mechanisms to deal with rare failures. It should include consideration of the following concepts:

(a) automation designed so that the air traffic controller who is supervising the traffic situation is able to provide backup ATC services to maintain safety. It is understood that these backup systems may not be as efficient as the first line of ATC.

(b) the controller provided with a backup system including monitoring and planning aids on displays driven by hardware and software which is independent from the main automation system. These backup procedures may be different than the system's normal procedures.

(c) capability of providing the pilot with information on nearby traffic.

(d) capability of providing the pilot with information on the runway occupancy, to instill pilot confidence in reduced terminal area final approach longitudinal separation standards.

(e) ATARS as a collision prevention backup for aircraft with DABS, in DABS ground station coverage.

(f) An Active BCAS capability as a collision prevention backup outside of DABS ground station coverage, or in the event of a DABS ground station breakdown.

(g) Adjoining facilities being equipped to provide backup control for each other.

(h) The ground system being required to continuously compute and update a set of backup clearances and communicate them via data link. The nature of the clearances will, of course, depend on the failure mode.

(i) Simulated failure training exercises for air traffic controllers and pilots being part of the process for maintaining proficiency in dealing with failures.

(4) The E&D program should include the immediate formation of a test team which is independent from the automation design team and has the continuing mission of looking for and characterizing possible failure modes, i.e., trying to "break the system". This effort would include testing for the automation system's ability to cope with unusual failures.

(5) The transition from existing hardware and software to a more desirable automation capability will be very complex. Research should be done on the transition from the 9020 system used in NAS today, to the desired hardware and software system. This activity must take into account the programs recommended in items 1 and 3 above, as well as Design Requirement 5 in Section 5.1. A possible technical solution to this problem is the use of a distributed processing architecture. This permits gradual step by step upgrades to the existing system which are compatible with the eventual desired system in hardware and software. The FAA should give strong consideration to such distributed processing concepts in addressing the 9020 replacement question. (Comparable statements may also pertain to TRACONs, but the group did not have time to look into this question in detail.)

(6) The development of automation capabilities outlined in the design requirement of Section 5.1 and Recommendations 1 through 5 involves the timely implementation and proper integration of many major ground system components including 9020 and ARTS replacements, DABS surveillance, ATARS, DABS data link services, new terminal and en route automation functions, and central flow control. In order to aid their development planning, and to provide users with a clearer understanding of FAA objectives, FAA should prepare and work towards implementation scenarios which result in the necessary systems being in the right place at the right time and properly integrated. These scenarios should be coordinated with the users.

(7) Research on a "Pilot-Based" ATC system should first identify the concepts for aircraft carrying the Integrated Traffic and ATC Information Display. Among the things one needs to know are:

(a) The ground system and airborne requirements to accommodate the new concept in the basic automation system,

(b) The benefits of these concepts compared to the future automation system, including safety and productivity,

(c) The number of equipped aircraft which are needed to permit use of the new concept.

(d) The effects on safety and workload in the cockpit.

(8) ATC concepts predicated on aircraft with 4D navigation equipment promise some useful benefits. The FAA should evaluate benefits that would be obtained if a minority of aircraft were equipped with 4D navigation equipment. If it appears that user benefits would encourage high levels of acquisition, ATC concepts predicated on 4D navigation should be considered.

(9) FAA E&D programs should explore potential techniques to centralize and automate the maintenance functions of performance assurance and fault diagnosis for software and hardware in the system. System designs should be developed to take advantage of these techniques. These efforts should also assess the resulting potential for increased productivity of FAA's maintenance force.

(10) From the beginning, human factors activities must be an integral part of automation program developments and design efforts. Within the context of the specific automation concepts which FAA pursues, meaningful human roles must be developed and shown to provide satisfactory performance. Research on methods for transitioning human roles is needed. Satisfactory methods of introducing automatic communications and computer decision making are crucial to achieving the desired goal of automation. Within, and central to, each of its automation activities which involve changing human roles, E&D should have adequate experimental programs looking into the relevant human factors issues.

(11) Possibilities for increasing productivity and reducing costs by consolidating ATC facilities (e.g., centers with centers, terminals with centers, etc.) should be investigated. Technical implications should be investigated so that new equipment to support automation does not inhibit consolidation. Approaches should be developed for transitioning to desirable new configurations.

(12) The FAA should present their response to these recommendations to the users not more than six months after formal submission of this report.

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APPENDIX G

AUTOMATION/PRODUCTIVITY GROUP LIST OF ATTENDEES

Robert Everett, Chairman

USERS

NAME	ORGANIZATION
Don Beach	NPA
William Cotton*	ALPA
Bill Fanning	NBAA
E. V. Fretwell	ALPA
William Horn*	NBAA
Charles Jorgensen*	DOD/CNO
Victor Kayne*	AOPA
Ed Krupinski*	ALPA
L. Homer Mouden	Flight Safety Foundation
Robert Papasodero	FAA/PATCO
William Russell*	ATA
C. Spencer	ALPA
Frank White	ATA

OTHER

NAME	ORGANIZATION
Ray Alvarez	FAA
Tom Amlie*	FAA AEM-200
Ken Angelo*	IBM
Dennis Best*	TI
Richard Bock	FAA ARD-250
Robert Buck*	FAA ARD
James Burghart*	Boeing
William Codner**	U.K. CAA

* This denotes principal participants who attended a majority of the group's meetings.

** As an observer.

NAME	ORGANIZATION
John Deluca	Burroughs
Paul Drouilhet	MIT/LL
R. L. Erwin	Boeing
Lawrence Goldmuntz*	ESP
Larry Hanes*	TI
William Harman	MIT/LL
Wayne Heston*	FAA ATF-4
Barry Horowitz*	MITRE
D. Hurley	FAA
Robert Jacks	United Airlines
William Jones	Burroughs
Will Kane*	CDC
Ed Koenke	FAA AEM-20
Pete Kovalick	FAA ATS
K. E. Larson	UNIVAC
Gene Lyman	NASA
Dave Mauritzen*	Magnavox
Art McComas*	Bendix
W. C. Meilander	Goodyear
Milton Meisner*	FAA
James Mollenauer	Consultant
Tom Morgan*	CSC
Herm Natanblut	Burroughs
Lingiam Odems*	USA/Aeronautical Suc. Off.
Peter O'Neil	USAF/XOODF
Vincent Orlando*	MIT/LL
Lee Page	FAA
Roger Phaneuf	Consultant
David Prior	Sperry-Univac

* This denotes principal participants who attended a majority of the group's meetings.

NAME	ORGANIZATION
Robert Rogers	Battelle
Paul Rubin	CSC
Sy Salmirs*	NASA-LRC
John Sigona	DOT/TSC
Wilfred Volkstadt	USAF/RDPE
Andres Zellweger*	FAA

* This denotes principal participants who attended a majority of the group's meetings.

NEW ENGINEERING & DEVELOPMENT INITIATIVES --
POLICY AND TECHNOLOGY CHOICES

CHAPTER II

AIRPORT CAPACITY
Topic Group 2

Final Report

1. INTRODUCTION

1.1 The Problem

In the December 1969 report of the Department of Transportation Air Traffic Control Advisory Committee (ATCAC) it was stated that:

> "The airport plant at a number of dense hubs is often saturated by present demand at peak hours. There will continue to be popular resistance to construction of new airports in major urban areas as a result of their high costs, the diffuse distribution of the benefits of aviation activity, increased noise, and political fragmentation. As a consequence, it is not reasonable to expect additional urban airports sufficient in number to satisfy the forecast demand even if increased use of V/STOL is taken into account. Major improvements in current airport capacity must be achieved. For public acceptance, this should be accomplished without increasing perceived aircraft noise."

The problem today is not substantially different from what it was in 1969. In the decade which has followed the drafting of the ATCAC report, the committee's assumptions concerning the construction of new airports in major urban areas has been proven to be a fact. The ability to produce major improvements in airport capacity while achieving public acceptance has not been achieved.

Unless additional airport capacity is provided, congestion at major terminals can be expected to be more severe in the future. With increases in airport congestion there are parallel increases in delays and the costs of delays. The total aircraft operating costs of certificated air carriers, due to delays experienced today, are estimated to be approximately $500 million per year. Unless in some way airport capacity is increased, these delay costs are projected to triple by the mid-1980s. Increased congestion, coupled with increased delay costs, may well stifle aviation's growth.

The Airport Capacity Topic Group has reviewed the various E&D programs underway at present to increase capacity. As a result of the briefings it has received and the reviews it has made, the Topic Group developed a series of recommendations for E&D initiatives to improve the capabilities of airports to more nearly meet the anticipated demand.

One question has haunted the Topic Group throughout its deliberations - Is any program for increasing airport capacity viable in light of the growing environmental pressure to stabilize or even reduce the number of operations at many major airports? Before this question can be answered affirmatively, a methodology for trading off future environmental improvements for increased operations at existing airports will have to be developed.

1.2 Activities

The Airport Capacity Topic Group held 9 formal meetings from April 11, to November 9, 1978. Announcements of meetings were mailed to all organizations and individuals who had expressed interest in the activities of the Topic Group. The Topic Group is indebted to various industry experts and to the FAA specialists who briefed the group as to status of programs underway and plans for future activity. The FAA made available to the group copies of reports and manuals as requested.

The Airport Capacity Topic Group focused on those airport capacity problems and issues dealing with and relating to the maximum number of aircraft operations on an airport in a given time as contrasted to a "consumer-oriented" focus which focuses on the number of passenger enplanements and of cargo processed in a given time at an airport.

This choice of focus was made purposefully so as to provide guidance to the FAA on those items which are institutionally and without challenge, a responsibility of the FAA.

The Topic Group defines airport capacity as the maximum number of aircraft operations (take-off and landings) which may be processed, irrespective of delay, in a given time at an airport under specific conditions of: (1) airspace constraints; (2) weather conditions; (3) runway layout and use; (4) aircraft mix; (5) percent arrivals; (6) exit taxiway locations; and (7) system variability. Airport capacity, as defined, is a calculated value expressed on an hourly or an annual basis.

1.3 Participants

The Airport Capacity Topic Group Participants are listed in Appendix A.

2. STATEMENT OF WORK

2.1 Mission

Even if it were environmentally and socially feasible to construct adequate additional airports in major urban areas, it would still be economically sound to attempt to increase the utilization of existing airports. By increasing the capacity of existing airports, the national resources that have been expended on the establishment, maintenance and operation of aviation facilities are utilized in a more productive mode.

The mission of the Airport Capacity Topic Group is to provide guidance to the government in the development of E&D plans and programs that will, hopefully, produce timely, acceptable end products that will increase airport capacity. Since most air traffic control and air navigation systems are cooperative - the accepability of the system concepts by the aviation industry is vital to the success of any of these systems.

2.2 Issues

The resolution of the airport capacity problem involves a large number of issues and subissues concerning jurisdictional authority and responsibility, concerning a complex of technical disciplines, the interaction of operational techniques and the control of natural phenomena. Early in its deliberations the Topic Group recognized that, within the short life span of the Group, it could not begin to investigate all pertinent issues. If it were going to produce an end product that would be helpful to the FAA, it would have to limit its activities.

After considerable discussion the Topic Group decided to limit its scope to a consideration of the nine following issues:

1. Metering and Spacing

   Can a Metering and Spacing System with goals of an interarrival accuracy of 11 seconds at the approach gate and eventually 8 seconds in more advanced systems be developed and incorporated into the air traffic control system?

2. IMC versus VMC Capacity

   Can airport capacity under Instrument Meterological Conditions (IMC) be made more nearly equivalent to that under Visual Meteorological Conditions (VMC)?

3. Reduce Separation Standards

   Can longitudinal and/or lateral separation standards be reduced to increase airport capacity?

4. Terminal Air Traffic Control

   Can independent approach, departure and missed approach procedures be developed to serve mixed aircraft operations to and from airports that might have parallel runways or dedicated runways for light aircraft and helicopters?

5. Class Sequencing

   Can airport capacity be increased by class-sequencing air traffic if the first-come, first-served principle is modified during peak periods of delay?

6. Runway Occupancy Time

   What actions can be taken to reduce runway occupancy time?

7. Wake Vortex

   What actions can be taken to reduce the adverse capacity effects of wake turbulence?

8. Aircraft Noise

   How can the aircraft noise influence on airport capacity be ameliorated?

9. Airport Landside Problems

   Are airport terminal buildings and airport access major constraints to increasing airport capacity?

10. Off-Airport Construction

    To what extent does off-airport construction impose operational constraints to airport capacity?

3. FORECAST OF CONGESTION

3.1 General

The forecast methodology used by the FAA for developing Terminal Area Forecasts is a top-down approach. That is, national growth factors for aircraft operations were applied to the base year data at individual airports to project future annual activity. The national growth rates thus were utilized as initial rates of growth for individual airports. Specific hub forecasts, the results of other forecast models and studies, and regional updates are then used to modify individual airport forecasts.

The aircraft operations growth rates were then adjusted in order to account for the capability of an airport to handle aircraft. Unless additional facilities such as runways or electronic equipment that can safely reduce separation standards are installed, as airports reach certain levels of operations, aircraft will tend to use other nearby airports. As a general rule, no expansion of airport facilities is assumed in the FAA forecast. When an airport approaches saturation, the growth of aircraft operations at that airport falls below national average growth rates. In the year after the present operating environment has been saturated, the forecasted total operations are assumed to be constant.

3.2 Terminal Area Forecast

A review of the FAA publication "Terminal Area Forecasts, Fiscal Year 1979-1990" dated June 1978, provides a rather grim outlook concerning the capabilities of today's high traffic density airports to meet the forecasted demand. For the purposes of this Terminal Area Forecast it was assumed that there will be no additional runways, runway extensions, or other enhancement of the existing facility at specific airports, and that the airport will be saturated when the forecast of total operations reaches twice the practical annual capacity.[1/] Based on these premises, the report forecasts that 26 airports in the U.S. will become saturated in the 1979-1990 period.

As an airport approaches saturation, operations become increasingly delayed or restricted, forcing users to seek alternative ways of overcoming these problems. Some flights will be moved to off-peak hours, some will move to other airports and some will be cancelled altogether. A review was made of those airports that will reach 90% saturation level by 1989. At the 90% saturation level these airports will experience about 40 minute peak hour delays with an average 7 to 8 minute delay per operation for the year. During the forecast period, 1979 to 1990, 60 airports are expected to reach 90% of saturation. Table 3-1 shows the list of airports

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[1/] In general, the practical annual runway capacity is defined (in FAA Advisory Circular 150/5060-1A) as that level of annual operations in which 10% of the operations exceeds the practical hourly runway capacity. Runway hourly capacity is defined as the level of hourly demand for two consecutive hours during which departure delay averages 4 minutes at air carrier served airports and 2 minutes at general aviation airports.

Table 3-1

AIRPORTS NEARING SATURATION PRIOR TO 1990

Year	City	State	Airport Name	Location Identifier	Operations in Thousands 90% Saturation	Unconstrained
1977	Washington	DC	Washington National	DCA	324	511
1977	New York	NY	La Guardia	LGA	360	529
1977	Chicago	IL	Chicago-O'Hare Intl	ORD	666	1051
1977	Denver	CO	Arapahoe Co	APA	360	556
1977	Tulsa	OK	Tulsa Riverside	RVS	288	458
1977	Santa Monica	CA	Santa Monica Muni	SMO	270	420
1978	Anchorage	AK	Merrill	MRI	360	526
1978	San Jose	CA	San Jose Muni	SJC	504	738
1979	Concord	CA	Buchanan Fld	CCR	360	530
1979	La Verne	CA	Brackett Fld	POC	270	367
1979	San Carlos	CA	San Carlos	SQL	270	420
1980	Islip	NY	Islip Macarthur	ISP	378	465
1980	Atlanta	CA	Dekalb-Peachtree	PDK	270	380
1980	San Diego/Santee	CA	Gillespie Fld	SEE	288	362
1981	West Chicago	IL	Dupage Co	DPA	324	436
1981	Boston	MA	Logan Intl	BOS	378	502
1981	Palo Alto	CA	Palo Alto	PAO	270	356
1982	Baltimore	MD	Baltimore-Wash Intl	BWI	306	394
1982	Philadelphia	PA	Philadelphia Intl	PHL	414	553
1982	Everett	WA	Snohomish Co/Paine Fld	PAE	288	335
1982	Fullerton	CA	Fullerton Muni	FUL	270	394
1983	Anchorage	AK	Anchorage Intl	ANC	360	422
1983	Norwood	MA	Norwood Memorial	OWD	270	305
1983	Atlanta	GA	Hartsfield Intl	ATL	630	674
1983	Charlotte	NC	Douglas Muni	CLT	288	317
1983	Fort Worth	TX	Meacham Fld	FTW	360	494
1983	Oxnard	CA	Oxnard	OXR	270	319
1984	Detroit	MI	Detroit Metro Wayne Co	DTW	306	360
1984	Seattle	WA	Boeing Fld/King Co Intl	BFI	504	649
1984	West Palm Beach	FL	Palm Beach Intl	PBI	288	328
1984	Houston	TX	William P. Hobby	HOU	378	472
1984	Carlsbad	CA	Palomar	CRQ	270	340
1984	Hayward	CA	Hayward Air Term	HWD	504	592
1984	Las Vegas	NV	Mc Carran Intl	LAS	360	471
1985	Lawrence	MA	Lawrence Muni	LWM	288	309
1985	Denver	CO	Stapleton Intl	DEN	540	672
1985	Mesa	AZ	Falcon Fld	P16	270	283
1985	Long Beach	CA	Long Beach	LGB	720	879
1985	Los Angeles	CA	Los Angeles Intl	LAX	540	730
1985	Santa Barbara	CA	Santa Barbara Muni	SBA	288	310
1986	Caldwell	NJ	Caldwell Wright	CDW	288	297
1986	Flint	MI	Bishop	FNT	324	335
1986	Dallas	TX	Addison	ADS	288	319
1986	Phoenix	AZ	Deer Valley Muni	DVT	360	371
1986	San Diego	CA	Montgomery Fld	MYF	504	558
1986	San Jose	CA	Reid-Hillview	RHV	504	523
1987	Des Moines	IA	Des Moines Muni	DSM	306	369
1987	Farmingdale	NY	Republic	FRG	288	394
1987	White Plains	NY	Westchester Co	BPN	324	329
1987	Newport News	VA	Patrick Henry Intl	PHF	270	300
1987	Dallas	TX	Dallas Love Fld	DAL	360	476
1987	Scottsdale	AZ	Scottsdale Muni	SDL	270	276
1987	San Diego	CA	San Diego Intl	SAN	270	294
1987	Reno	NV	Reno Intl	RNO	270	271
1988	Morristown	NJ	Morristown Muni	MMU	288	349
1988	Honolulu	HI	Honolulu	HNL	504	319
1988	Denver	CO	Jeffco	BJC	324	384
1988	Albuquerque	NM	Albuquerque	ABQ	324	333
1988	Dallas-Ft. Worth	TX	Dallas Ft. Worth-Rgl	DFW	540	560
1989	Houston	TX	Houston Intercontinental	IAH	360	400

Source: FAA's "Terminal Area Forecasts, Fiscal Year 1979-1900", June 1978.

nearing saturation. If these airports are assumed to operate at the 90% level of saturation by 1989 there will be nearly 22 million operations at these airports and a total of 207 million enplanements at these 60 airports. However, if these airports are not constrained at 90% of the saturation level, and the assumption is made that the facilities can be expanded, modified and improved, and the air traffic control and navigation system modified to accommodate the potential unconstrained demand, the number of operations at these 60 airports could increase to 27 million. Thus with operations held at 90% of saturation, approximately five million operations will be lost or diverted from these airports. Of the 60 airports reaching 90% of saturation prior to 1990, 32 are air carrier airports and 28 are general aviation airports.

There are over 12,000 airports, of one type or another, in the United States. In many areas of our nation we have a comfortable surplus of airport capacity. The airport capacity problem stems from the simple fact that demand for airport services is not evenly distributed, but is concentrated usually in areas of high population density. Currently 92% of all air carrier passengers are enplaned at the top 100 air carrier airports. In 1977 the top five air carrier airports - Chicago's O'Hare, Atlanta, Los Angeles, New York's JFK and San Francisco - enplaned nearly 28% of all air carrier passengers.

4. OPPORTUNITIES FOR CAPACITY INCREASES

4.1 General

In its review of the FAA programs designed to increase airport capacity, the Airport Capacity Topic Group found that the program emphasis was concentrated on the development of components and subsystems rather than on the development of a total airport system in which all of the components and subsystems would interact effectively and efficiently in order to perform the major system functions. Little or no attention is paid to the fact that airport geometry, runway surface texture, operating strategies, weather collection and distribution, air traffic control techniques and hardware, air navigation aids, airspace capacity, and all other components of the airport system - all interact on one another and are mutually interdependent. The excellence of the total airport system is dependent upon the ability of the system components and subsystems to interface properly and to support one another.

Although management has made efforts to consolidate projects into programs, there is no focal point within the E&D structure - nor any organization - charged with the responsibility for planning and executing a total E&D airport program.

The Topic Group also concluded that there is a requirement that a means be developed to determine how components, subsystems and techniques would operate as part of a total airport system. Before new components, subsystems or techniques are introduced into the terminal area, a determination should be made as to the need for and the most effective method of using them.

It was recognized that the E&D products must ultimately be applied in airport site-specific situations and therefore the establishment of some requirements for E&D programs should be developed on an airport specific basis. The means to accomplish this already exists in the Airport Improvement Task Forces. These task forces which were organized by FAA to recommend terminal system improvements at specific airports and consist of local requirements drawn from industry and government, can help to develop E&D requirements on an airport-specific basis. The expertise, local knowledge and working relationships developed in the task forces provide a unique opportunity to develop and document insights concerning the operations of these airports and to examine the local E&D requirements. The task forces have established demand-capacity-delay relationships which illustrate how delays to aircraft will increase in the future in the absence of E&D improvements.

The Topic Group felt that some action should be taken to overcome these deficiencies and therefore recommends:

1. That the planning and execution of the total airport system E&D program be concentrated in a single organizational entity within the FAA E&D structure whose sole responsibility is this program.

2. That the FAA develop a plan for determining how the total advanced terminal system (both airborne and ground based) would be operationally utilized, and to develop the capability to test, evaluate and demonstrate the effectiveness of the system.

3. That airport site-specific elements be identified and considered in the development of E&D requirements.

4.2 Method of Approach

As has been previously implied, one of the most effective means of increasing airport capacity would be the construction of additional airports in major urban areas. If, however, it is not feasible to construct the additional capacity, what other opportunities do exist to increase the utilization of existing airports and thus increase airport capacity? Since airport capacity is primarily dependent upon:

1. The accuracy with which delivery of aircraft for final spacing is made;

2. The permissable longitudinal separation minima;

3. The runway occupancy time utilized; and

4. The airport geometry,

the Topic Group examined these four factors to determine where opportunities for airport capacity increases exist, and to identify the kinds of facility improvements needed to take advantage of them, together with the impact on the necessary E&D programs. This report has grouped the pertinent statement of work issues under the above four factors.

4.3 Accuracy of Delivery

By increasing the accuracy of delivery of aircraft for final spacing and by making interarrival spacing more consistent, an increase in runway utilization is assured and airport capacity is increased.

4.3.1 Metering and Spacing

One of the major objectives of the FAA E&D Program for the development of a "Metering and Spacing System" is to increase the accuracy of the delivery of aircraft for final approach spacing. Metering and Spacing as applied to the operation of a specific airport or a specific terminal area includes all activities necessary to plan and regulate the rate, order and separation of successive arriving or departing aircraft that are utilizing common airspace and/or common or interfering landing or take-off surfaces.

The FAA Metering and Spacing (M&S) Program is closely coupled to developments in many other E&D programs in that the hardware, software and procedures developed for M&S must be compatible with inputs/outputs and performance capabilities of other subsystems (WVAS, RNAV, MLS, DABS, Data Link, etc.). The full airport capacity increase potentials that may be provided by other subsystems may not be realized unless and until interface with M&S can be effectively implemented.

The stated objective of the Metering and Spacing Program is to "improve system capacity through the development of automation aids to support controllers in sequencing, metering and spacing of traffic arriving and departing high activity airports." Simulation efforts conducted at NAFEC indicate that, under certain conditions, proficient air traffic controllers can equal the accuracies of delivery of aircraft to final approach achieved by M&S, but the average is in the range of 18 to 21 seconds. Nevertheless the Topic Group believes that to achieve the consistency of accuracy required and to utilize fully the potentials to increase airport capacity of aids, such as RNAV, the Microwave Landing System and the Wake Vortex Avoidance System, and in order to enhance the performance of such other real time processing functions as tracking and hazard assessments, the development of an automated implementable M&S system, interfaced with en route M&S, is essential. To achieve higher runway utilization rates, automation assistance is needed to provide increased consistency and precision in the organization and delivery of aircraft operating into and out of high density airports. Metering and Spacing automation serves to aid in determining the rate at which aircraft may be accommodated in the terminal area, the appropriate sequence of flights in the arrival/departure streams, and the attainment of minimum intervals between operations in consonance with separation criteria. It also provides a source of current air traffic control data to enhance the performance of such other real time processing functions as tracking and hazard assessment.

In current operations the regulation of rate, order and separation of arriving/departing aircraft is accomplished through the combined efforts and judgment of a team of controllers made up of the local controller located in the tower cab and arrival/departure controllers in the operating quarters (IFR Room) of the TRACON.

Current control methodology requires very close coordination of each controller's actions, and system efficiency is dependent on the capabilities of the controllers to continually extrapolate and determine those control actions that are presently necessary to bring about the desired future results. As traffic volume increases at a specific terminal, the job gets extremely complex and with the introduction of additional variables in the spacing criteria to be applied (such as the -3, -4, -5, and -6 nautical mile spacings required by wake vortices) the job can become overwhelming.

The M&S concept is aimed at providing computer capabilities to assist in the performance of the metering and spacing functions. The E&D efforts in this program entails the design and development of software capabilities incorporating adaptive sequence and control logic, time and space computation algorithms, versatile control geometry and input/output features that will enable:

1. Determination of realizable arrival/departure sequences, intervals and schedules for optimum utilization of available runways.

2. Metering of arrivals from terminal entry points and release of departures awaiting takeoff clearance at rates and times consistent with schedules, separation minima and limitations of control geometry.

3. Application of fuel conservative flight profiles.

4. Continual assessment of flight progress and determination of control actions necessary to maintain schedule/spacing conformance.

5. Dynamic adjustment of stored wind values on the basis of achieved vs. anticipated flight paths and ground speed.

6. Dynamic revision of schedules/sequence when variations from anticipated performance exceed the range of control adjustment.

7. Application of varied separation minima based on the type/category of particular aircraft pairings.

8. Adjustment of minimum separation values on the basis of inputs and updates from a wake vortex prediction system.

9. Formulation and transfer of messages to the associated en route control system conveying such data as expected approach clearance times applicable to each inbound flight, fix/altitude availability, average arrival delays and acceptance rate forecasts.

Initially computer generated metering and spacing instructions applicable to the individual aircraft will be displayed to the appropriate controller for delivery via voice communications. Following implementation of DABS, it is expected that delivery of metering and spacing instructions may be via the DABS data link.

The M&S Program Plan as presented to the Topic Group consists of the following phases:

1. Basic Arrival Metering and Spacing: Design, development and debugging of appropriate software modules, as well as integration and verification of the capabilities with a basic ARTS III configuration and such other hardware components as may be necessary to support field trial efforts. Dynamic simulation and live flight verification tests under controlled conditions to be conducted at NAFEC. Following initial shakedown at NAFEC, the capabilities will be added at a representative ARTS III site for appraisal under operating conditions in the field.

2. Implementable Metering and Spacing: The objective of this phase is to establish an arrival metering and spacing capability suitable for field implementation.

3. Metering and Spacing Expansion: This activity encompasses a number of efforts that involve additions to or modifications of the arrival metering and spacing.

   a. Departure Metering and Spacing

   b. RNAV Metering and Spacing Integration

   c. DABS and Data Link Integration

   d. Wake Vortex Prediction

   e. Microwave Landing System Integration

An experimental version of the Metering and Spacing System - the Basic Arrival M&S - has been developed and has been integrated with the ARTS III system and is currently under test and evaluation at the National Aviation Facilities Experimental Center (NAFEC) in Atlantic City, N.J. No finite timetable is available as to when live flight operations at a representative site under normal operating conditions will be conducted.

The Topic Group found no fault with the M&S program objective nor with the program plan, however, it was critical with respect to the progress made to date.

In spite of the fact that the M&S concept dates back to the early 1960s, work to date has been limited to the development of the Basic Arrival M&S System. The Topic Group recognizes that considerable time was lost due to underestimating, by both government and industry, the complexity and difficulty of developing the required algorithms and software. The length of time that M&S has been under development has raised serious questions as to whether or not the concept is technically feasible or operationally applicable. The Topic Group believes that the program goals are technically achievable, but until the system is tested and evaluated under normal operating conditions with live flight operations, no judgment concerning its operational use can be made.

The M&S system, in the opinion of the Topic Group, is the critical subsystem in the total airport program to increase airport capacity. In order to proceed into and through the second phase of the program plan - the development of an implementable M&S system - the capabilities for extensive and realistic dynamic simulation and for live flight verification activities under both controlled conditions and normal operating conditions will be required. It is essential that E&D management recognize these needs and acquire such capabilities as soon as possible.

A question has been raised concerning the capacity of the ARTS III computer to handle both the M&S functions and the ARTS expansion program. The Topic Group concluded that the present capacity of the ARTS computer should in no way constrain the M&S development.

To maximize the effectiveness of metering and spacing, the aircraft should be under M&S control from departure to final approach. En route metering and spacing is under development by FAA. The en route and terminal metering and spacing systems interchange information and are mutually interdependent. The en route system will receive from the terminal system the expected approach clearance times applicable to each inbound flight, fix/altitude availability, average delays and acceptance rate forecasts. Terminal systems will be dependent upon the en route system's capability to deliver aircraft to control transfer points in accordance with the plan of the terminal M&S system and with a specified accuracy (1-minute). Both the FAA operating service (Denver Air Traffic Control) and Systems Research and Development Service have efforts underway to develop en route M&S systems. The Topic Group is of the opinion that the effectiveness of a terminal M&S system varies directly with the size of the control area in which the system is utilized. The area of responsibility of the terminal M&S must be sufficiently large to permit the accomplishment of the system mission. Control transfer points might well be moved out into today's en route area.

The delivery accuracies required to reduce longitudinal spacing to 2.5 nautical miles or even to 2.0 nautical miles are within the design goals of M&S.

Simulation work has demonstrated that interarrival accuracies (1-sigma) of 11 seconds for the basic system and ultimately 8 seconds in more advanced systems, are technically achievable. Thus the importance of the role of M&S in increasing airport capability becomes very evident. The M&S system must be able to provide conflict free vectors.

The question as to whether aircraft under various wind conditions and with the average pilot can respond to M&S instructions so as to achieve the desired delivery accuracies has been raised. The Group concluded that not until flight tests and demonstrations and a full field evaluation of the M&S system, using live aircraft operating under various weather and runway conditions in a normal operating environment are completed, will it be in a position to resolve the issue.

Although the Basic Arrival M&S System does not have the capability to feed multiple parallel and intersecting runways with the desired staggers in arrival time, there is no technical reason to doubt that such capability can be developed. The first implementable metering and spacing system will have provisions to accommodate simultaneous arrival operations to dependent and independent parallel runways and to independent non-parallel runways.

Whether or not M&S can aid in releasing departures so as not to interfere with subsequent arrivals or prior departures on a complex set of runways has not been resolved. Only after the departure functions are added to the Basic Arrival M&S system will the level of assistance that M&S can provide in releasing departures be determined.

The Topic Group is of the opinion that the use of a display of traffic information located in the cockpit might improve the effectiveness of M&S. The group believes that such a display, used in conjunction with M&S, might improve the accuracy of delivery and accelerate pilot acceptance of the system.

4.3.1.1 M&S Conclusions and Recommendations

The Airport Capacity Topic Group determined:

1. That M&S can effectively improve aircraft delivery precision and therefore can contribute to airport capacity increases.

2. That from initial simulation work already accomplished it may be concluded that it is technically feasible to develop an M&S system that will deliver aircraft with sufficient accuracy to permit longitudinal separations down to 2 nautical miles.

3. That the completion of the Basic Arrival M&S System simulation, live flight verification tests and field appraisal in various weather and runway conditions and under normal operating environment be expedited. In this regard, it is essential that a plan for field appraisal be developed and approved as soon as possible. The field test may be conducted at a low density ARTS III site of minimal terminal area complexity.

4. That action toward the development of an implementable M&S capability be initiated as soon as possible. Additional simulation work will be required and should include a determination of missed approach rates, for example, as well as efforts to integrate M&S with terminal area flow management.

5. That before a national implementation program for M&S is launched, a technical analysis of the field trials should be made to determine the quantitative improvement of delivery precision made by the addition of M&S to the present manual system.

6. That close coordination between En Route and Terminal Area M&S development programs be accomplished to assure the two-way effectiveness of the interface between these systems.

7. That an investigation be made to determine the advantages of expanding the area of coverage of the *Terminal M&S System*.

8. That expansion of the arrival only M&S to provide for departure metering and sequencing servicing be accomplished so that this feature may be phased into the air traffic control system as soon as possible.

9. That concepts and procedures necessary to use advanced airborne systems - such as 4D RNAV, MLS, CDTI, etc. - and capabilities effectively in an M&S environment be investigated and determined.

10. That the value of a cockpit located display of traffic information used in conjunction with M&S be determined through simulation and flight test as part of the ongoing CDTI program.

11. That M&S modifications be determined and developed to:

   a. Accommodate efficiently fuel conservative profile descents.

   b. Realize maximum advantages from DABS data link.

   c. Interface and integrate effectively M&S with VAS and WVAS.

4.4. Longitudinal Separation

A review of capacity analyses of eight airports in major urban areas (John F. Kennedy International, La Guardia, Atlanta, Miami, Denver, Los Angeles, San Francisco and O'Hare) made by the FAA indicates that the most significant capacity increases could be gained through the reduction of minimum longitudinal spacing. What will be required to permit a reduction in this separation standard? The Topic Group started its search for an answer to this question by examining the basic differences between flight under Visual Meteorological Conditions (VMC) and flight under Instrument Meteorological Conditions (IMC).

4.4.1 Making IMC Capacity More Nearly Equal to VMC Capacity

One of the major goals of an FAA E&D Program should be to raise the IFR capacity of the major airports to more closely match the capacity available under good visibility conditions. IFR capacity, as used in this report, refers to the capacity of the airspace/runway complex with all IFR rules (i.e., lateral and longitudinal radar separations) in effect. VFR capacity refers to the operation of the terminal IFR system with the relaxation of radar separation and navigation requirements (i.e., visual approach and separation procedures) on final approach.

At present the IFR capacity of the major airports is only 60 to 80% of the capacity available under VMC. The current air carrier and commuter schedules (in the form of quotas at JFK, LGA, ORD and DCA) - and to a lesser extent, the base general aviation demand - are constrained by the IFR capacity which is well below the VFR potential of the facility. It is clear that similar considerations come into play at non-quota airports as well, when IFR saturation is approached. The result is overutilization of the facility in IFR and underutilization in VFR, with or without quotas. Thus a primary requirement on E&D for the improvement of the Air Traffic Control System should be the development of capabilities to more nearly equalize the capacity of major airports under the widest range of weather conditions.

Although efforts can be made to achieve optimum configurations of runways and airspace, and to remove the capacity restrictions imposed by limitations of noise abatement; the ultimate limitation to achieving maximum utilization of any runway complex will be the structure, precision and standards of the IFR terminal control and delivery process.

To meet the requirement of a more VFR-like terminal ATC system, E&D must provide the Air Traffic Service and the user communities with the means to:

1. Reduce the interarrival spacings employed in IFR, while

a. maintaining or improving the accuracy of the process that delivers the aircraft to the runway, and

b. reducing present vortex separation standards or eliminating the capacity limitations caused by trailing wake vortices.

2. Reduce minimum permissive lateral spacing between independent parallel runways.

3. Reduce capacity limitations due to missed approach interaction.

How much reduction in longitudinal separation standards should be made? Figure 4-1 provides a clue. The top matrix represents the Controller Handbook minimum final approach standards, while the bottom matrix represents the derived minimum spacings that would be obtained were VFR operations at major airports controlled as they are under IFR. The bottom matrix was developed from data collected at major airports and is the result of the hybrid radar/visual approach control process employed at busy airports that have a preponderance of jet traffic. It can be concluded that an important means to meet the requirement of equalizing IFR and VFR capacity is to provide the capability to reduce the basic IFR final approach separation standard from 3 NMI to 2 NMI with corresponding reductions in vortex related standards.

Since the present IFR approach system operates with a 3 NMI minimum and the corresponding VFR system operates with an average spacing below 3 NMI, then no amount of improvement in the control process will bring IFR capacity up to the level of VFR. Conversely, however, equally compelling arguments can be made that reductions in IFR approach separation standards (by whatever means) will require improvements in the precision with which that final approach spacing is achieved (again by whatever means). This improvement serves several purposes:

1. As a trade-off (in buffer size) against the amount of spacing reduction needed to achieve a desired level of capacity.

2. Control the rate of go-arounds induced by runway occupancy problems.

3. As assurance of a constant or improved safety level (i.e., avoidance of induced risks of air-to-air or runway collisions, or through increased numbers of go-arounds).

All this implies that reduced spacings and improved delivery precision must, in any realization of a future system, be highly interdependent.

Lead \ Trail	Sm	Lg	Hvy
Sm	3	3	3
Lg	4	3	3
Hvy	6	5	4

MINIUMUM IFR SEPARATION STANDARDS
(nmi)

Lead \ Trail	Sm	Lg	Hvy
Sm	1.9	1.9	1.9
Lg	2.7	1.9	1.9
Hvy	4.5	3.6	2.7

DERIVED MINIMUM VFR SEPARATIONS
(nmi)

Figure 4-1

TODAY'S SPACING MINIMA

Small = below 12,500#
Large = 12,500# - 300,000#
Heavy = over 300,000#

Problems concerning reducing or eliminating the hazards of trailing wake vortices are covered in Section 5 "Limitations to Airport Capacity" of this chapter. At present, however, it should be stated that no reductions below 3 NMI spacing on final approach appear feasible without the development of an acceptable solution to the wake vortex problem. Lateral spacings between parallel runways and missed approach interaction are discussed in Section 4 "Opportunities for Capacity Increases".

Having concluded that the VFR/IFR gap can be narrowed by reducing final approach spacing and by improving the accuracy of the delivery system, the Group looked at three alternate means of achieving these objectives.

The FAA approach to the problem is a ground based alternative premised on the capabilities of the Metering and Spacing System previously described. The M&S system would provide improved delivery precision and reduced final approach spacing would be contingent on the capabilities of M&S, reduced runway occupancy time, controller visibility through an improved airport surface surveillance system and direct controller-pilot access for go-around.

The other two alternatives involve placing a level of spacing authority in the cockpit.

One system hopes to achieve efficient aircraft delivery to the threshold based on a variant of a 4D RNAV with a schedule of times over waypoints, which may be M&S derived, and data linked from the ground. It is the pilot's responsibility to arrive over the designated waypoints at the indicated times. Monitoring and update information would be provided by the controller.

The other system attempts to achieve self-spacing through the use of 4D RNAV and a cockpit display of traffic information (CDTI). 4D RNAV would be used for precise delivery at the runway threshold. The cockpit display would be for crosscheck, runway monitoring and pilot assurance.

The Topic Group received briefings from proponents of the two self-spacing alternatives. Many hybrid systems can be postulated from parts of these three alternatives.

After considerable discussion and after a careful review of the FAA's basic program, the Topic Group considered the question as to whether or not the technological risk in the FAA program is so great that an alternative approach should be funded. The deliberations led to the conclusions that, even though there is a level of technological risk involved, the Group felt that there is sufficient promise of success that the development of the FAA M&S system should be pursued, as a matter of high priority, with the idea that M&S would be the basic

component of the future high traffic density terminal air traffic control system. This conclusion was premised on the assumption that adequate resources (money, people and plant) would be allocated to the program and that the program would enjoy top management support.

The Group also concluded that, since pilot assurances of safe spacing and a clear runway would be required in order to obtain pilot acceptance of reducing present IFR final approach spacing, the functions and the role of the cockpit display should be determined and defined by intensive simulation and flight testing.

Both 4D RNAV and Cockpit Display techniques should be explored and tested as a follow-on development of M&S, so that the best of each technique may be properly integrated into the future system. The Topic Group also discussed the possibility of using a CDTI at airports, which would not qualify for M&S installations but which might have DABS coverage, in order to increase peak hour capacity at these airports.

4.4.1.1 Weather

The maximum use of the air traffic control systems is achieved through the most effective management of the air traffic. One unexplored potential is that to be gained from providing the Air Traffic Service with a tailored weather service. This service would provide weather intelligence, both current and forecast, tailored with the detail needed to aid in the terminal area decision making processes so as to minimize the impact of weather on the efficiency of the operation. The weather intelligence also could be made available to the pilot for his decision making.

It is assumed that detailed knowledge of the location and duration in space of severe weather (turbulence, icing, and wind shear) and its severity and the changes that occur with time can help to minimize the effect of short term anomalies on capacity. Similarly, accurate forecasts of other weather changes, such as duration of visibilities below airport operating minima, shifts in wind direction and speed requiring changes in operating configurations, can minimize the impact on capacity.

The FAA aviation weather program plan proposes system improvements in needed weather intelligence. The Topic Group, however, felt that the impact of weather on terminal operations was sufficient to require that the effect of weather anomalies on the system be assessed.

4.4.2 Airport Rotating Beacon

One of the techniques utilized by air traffic controllers to reduce longitudinal separation and increase airport capacity is to offer pilots, when meteorological conditions permit, the opportunity to make a visual approach. Since there is no legal requirement for airport rotating beacons, in the last few years these beacons have been removed from service at some high traffic density airports. In built-up urban areas, due to the number of confusing background lights, it is often difficult at night to locate the airport visually. The absence of the rotating beacon makes this even more difficult and pilots have become more reluctant to accept visual approaches into airports without airport rotating beacons. The cost of maintaining and operating the airport beacon service, the Topic Group concluded, is trivial compared to the benefits that may be obtained.

4.4.3 Visual Approach Slope Indicators

There are numerous occasions when several runways at a particular airport could be utilized concurrently. Pilots will almost always seek to use a runway equipped with .electronic vertical guidance, i.e., a glide slope, wind conditions permitting. Runways equipped with VASI systems will be accepted as a second choice, however, runways without any vertical guidance are routinely shunned. Since there are many runways without any type of vertical guidance system installed that would otherwise be available to turbine-powered aircraft, runway utilization potential suffers due to this deficiency.

4.4.4. Class Sequencing

The conventional procedure of first-come, first-served in air traffic control may achieve equity in some situations but it also may incur additional economic costs at the same time. Sequencing of aircraft to takeoff and landing at airports in accordance with their performance characteristics can result in increases in the efficiency of airfield operations, thereby reducing airfield congestion during peak hours.

Speed control was introduced many years ago in the air traffic control separation standards when longitudinal time separation was reduced between slower aircraft following faster aircraft. In the late 1950s, by regulation, aircraft were required to reduce to 250 kts in certain high density terminal areas. This regulation was imposed in an effort to enhance the "see-and-be-seen" concept.

Subsequent to the Staten Island midair collision in the early 1960s, additional speed controls were imposed on turbine-powered aircraft that required a reduction to 250K below 10,000 feet msl within 30 miles of an airport. It is interesting to note that initial imposition of this regulation was the result of pilots' difficulty in

precisely navigating under IFR at high speeds at low altitudes in terminal areas. Later, the rule was imposed throughout the national airspace system below 10,000 msl to improve the see-and-avoid concept.

The most important use of speed control is employed by air traffic controllers within terminal areas for both departing and arriving aircraft. Rather complicated techniques must be followed to ensure that aircraft remain within safe speed ranges. However, it is used extensively and is a most effective tool in the expeditious handling of aircraft.

Speed control, therefore, is nothing new and has been employed for a number of years in air traffic control.

Traditionally, the first-come, first-served principle has been a basic precept of the aviation industry. Basically, first-come, first-served means that the first aircraft to arrive will land first and the number one aircraft at the departure position will be cleared for takeoff first. Another meaning of first-come, first-served means that an aircraft at an assigned altitude has priority over other aircraft requesting that altitude. In fact, the first-come, first-served principle is spelled out in the air traffic controllers manual under "Operational Priority" which requires that air traffic control service be provided on a "first-come, first-served" basis as circumstances permit with a few exceptions. Emergencies, ambulance, search and rescue, flight inspection, and presidential, as well as certain military activities are afforded expeditious or priority handling. In actual practice first-come, first-served does not always work nor is the principle always followed. For example, fixed wing special VFR flights are approved only if departing and arriving IFR flights are not delayed. Another example is that practice instrument approaches are generally delayed for arriving and departing aircraft.

What we have seen then is that all aircraft are not handled equitably on a first-come, first-served basis, as conditions sometimes require that priority be given to other aircraft. Further, pilots of other than "heavy" aircraft often voluntarily give way or delay their departure following a "heavy" aircraft due to wingtip vortices.

An FAA sponsored study[1/] suggested that a speed sequence could be set up if each aircraft has a speed at least equal to the preceding aircraft and that whenever a slower aircraft arrived, a new sequence could be started. However, this led to large delays for individual aircraft and appeared to discriminate against slower aircraft. Other combinations of sequencing were studied but the task seemed difficult because of such factors as: (1) Discrimination against slower aircraft; (2) Vast computer requirements to rearrange the arrival sequence whenever a new aircraft entered the arrival sequence; (3) Disregard of the first-come, first-served principle; and (4) Inability to move aircraft around as the

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[1/] MITRE Report MTR 4102 Revision 2 "Models for Runway Capacity Analysis", December 1972.

sequence changed, due to limited airspace. The report concluded, however, that speed class sequencing would provide benefits under a highly automated approach system where the computational power and traffic load are available to exploit this technique.

Control of traffic in high density terminal areas is one of the most difficult jobs of air traffic controllers. Arrival aircraft come from many different directions and from many different altitudes to land on a limited set of runways. If all aircraft landed at identical speeds (and wake vortices were not a factor), the first-come, first-served principle would be as good as any other procedure. Arrival sequences are inefficient when slower aircraft are intermixed with faster aircraft. If the first-come, first-served principle is modified, computer sophistication could be employed to reduce controller workload and improve system performance.

The Topic Group reviewed the MIT study report "The Dynamic Scheduling of Aircraft in the Near Terminal Area". This study proposes as a solution to the speed class sequencing a technique called Constrained Position Shifting (CPS). CPS would limit the number of slots an aircraft might lose in its landing sequence.

The study found that in simulation, first-come, first-served (FCFS) versus CPS with aircraft speeds ranging from 110K to 160K, no aircraft shifting more than 4 positions and 45 aircraft per hour arriving, the following results were obtained:

	Average Delay	Max. Delay	No. of Aircraft Delayed
FCFS	1688 sec.	3751 sec.	491
CPS	956 sec.	2577 sec.	485

The theoretical study of speed class scheduling indicated that the use of CPS did: Increase the capacity of an airport, decrease the average delay of all aircraft involved in the model, treat aircraft with similar speeds equitably, treat individual aircraft equitably, indicate particular success during peak periods, show that present computers have the capability of handling CPS. However, there are practical limitations which may reduce the achievable capacity benefits from class sequencing.

After discussing the advantages and disadvantages of class sequencing the Topic Group found that there was sufficient potential airport capacity increase in class sequencing techniques to warrant further study to determine their real-world potentials.

4.4.5 Microwave Landing System

The magnitude of the adverse capacity effect of mixing slow and fast aircraft in the final approach trail is dependent upon the length of the common approach path. The adverse effect is minimized as the path is shortened and segregated. The inherent characteristics of the Microwave Landing System, coupled with M&S and WVAS, may pemit turn ons to final approach much closer to the runway threshold than current practice. In addition to the above, its precision may make reduced lateral separation between independent parallel approaches possible.

4.4.6 Longitudinal Separation Conclusions and Recommendations

The Airport Capacity Topic Group determined:

1. That one of the major goals of the FAA E&D program should be to raise IFR capacity to more nearly equal the capacity under good visibility conditions. To reduce the IFR/VFR gap, E&D must be able to reduce interarrival spacing under IFR, improve the accuracy of delivery of aircraft to the runway and reduce the hazards of wake vortex. In attempting to equalize IFR and VFR capacities basic (non-vortex) IFR separation standards must be reduced.

2. That there is a great capacity payoff in the concurrent reduction of IFR longitudinal separation and the improvement of delivery precision.

3. That the development of M&S be pursued as a matter of priority, with the intent that it would be the basic component of the future terminal area air traffic control system.

4. That a need for a cockpit display of traffic information should be evaluated to determine its application in providing pilot assurances of safe separation and a clear runway.

5. That both 4D RNAV and CDTI techniques be explored and tested so that the best of each technique might possibly be integrated into the future ATC system.

6. That the MLS, and MLS coupled with M&S, WVAS and other advanced systems, be evaluated as a potential for increasing capacity through path shortening, reducing common approach paths, reducing lateral spacing, etc.

7. That the FAA assess the effect of weather anomalies on the ATC system and make a value analysis of the contributions made by improved

weather information on the ATC system. FAA should then develop those improved weather detection and display techniques for the terminal controller deemed effective.

8. That the FAA require an operating airport rotating beacon at every airport with a published instrument approach procedure.

9. That, due to the potential of reducing delays and increasing capacity, the FAA should evaluate class sequencing further, identify the benefits to be obtained and if found operationally feasible, develop a procedure to implement the sequencing mechanism as part of the M&S expansion program.

10. That a VASI system should be installed on every runway authorized for use by turbine-powered aircraft whenever that runway is not equipped with an electronic glide slope.

4.5 Runway Occupancy Time

4.5.1 The Current Situation

Existing ATC Procedures require that under IFR the time between consecutive landings must permit the lead aircraft to taxi clear of the runway before the trailing aircraft crosses the runway threshold. However, runway occupancy time at the present time is not a serious problem at air carrier airports because aircraft under IFR must maintain 3, 4, 5 or 6 NMI longitudinal separation on approach and this allows ample time for aircraft to clear the runway.

The Topic Group reviewed Report No. FAA-EM-78-9 "Analysis of Runway Occupancy Times at Major Airports" and found that, from data collected in 1972 and 1973, the mean runway occupancy times ranged from 40 to 60 seconds. The majority of times it fell within the 47-57 second range. As might be expected, the mean occupancy times for heavier and larger aircraft were generally higher than for lighter and smaller air carrier aircraft.

Several airports currently have angled exits which were installed to reduce runway occupancy times, but most are used at low speeds or on a sporadic basis. The Topic Group discussed the many factors that influence the use of angle exits and thereby influence runway occupancy time. The most significant factor appears to be the relationship of the terminal (and, of course, the specific carrier's location within the terminal) to the runway and the angle exits. Other factors motivate the pilot's use of the angled exits, such as the company procedure which establishes optimal speeds or exits at which a pilot should exit and a company's goal to minimize the time it takes to reach the air carrier's gate.

The Topic Group found that, given the exits that currently exist and the proper motivation, it appears that there is significant potential for reductions of the overall runway occupancy time in the short term. These potential reductions could approximate three to eighteen seconds below mean runway occupancy times currently achieved.

4.5.2 The Future ATC System

As previously stated, in order to accommodate the traffic increases anticipated, the future ATC system will have to permit longitudinal separations below today's minimum standards. These reduced in-trail separations will also reduce the available runway occupancy times. The full benefit of reduced separation standards will not be realized unless runway occupancy times are reduced. Increased safety, as well as the need for additional capacity, provides a further motivation to reduce runway occupancy time.

4.5.2.1 Runway Occupancy Time - Reduction Potentials

Landing procedures of transport aircraft are made up of three separate phases - the flare maneuver, the interval between where the main gear touches down to the point where the nose-wheel touches down, and the ground braking distance and roll. Runway occupancy time consists of the time it takes to execute these three maneuvers and to make a safe exit from the runway. The FAA report indicated that the first two phases take between 7 and 11 seconds and remain approximately unchanged for different types of airplanes within the present fleet of commercial aircraft. The last phase depends on many factors including the aircraft braking capability and on the pilot's technique and preference, as well as the location of exits on the runway. The time related to slowing down and making a safe exit is between 15 and 35 seconds. Therefore, the total runway occupancy time theoretically should lie somewhere between 22 and 46 seconds.

4.5.2.2 Reducing Runway Occupancy Time

There are many available options and combination of options that may reduce Runway Occupancy Time. The Topic Group recognized that considerable E&D efforts have already been expended by both government and industry to reduce Runway Occupancy Time, however, the Topic Group considered the following options and found them worthy of further study:

- High Speed Exit Taxiways
- Runway Grooving
- Drift-off Areas
- High Speed Entrance Ramps

The Topic Group also discussed the effect of the use of Dual Lane Runways and Staggered Dependent Dual Lane Runways on the requirements to reduce runway occupancy times.

Exiting at optimal locations or stopping in the minimum amount of time become meaningless if for one reason or another a pilot has no incentive to approximate these performance standards. A runway exiting system is of little value unless it is consistently used by the pilots. The Topic Group discussed the following factors upon which pilot acceptance of the system is dependent:

1. The pilot transfers from the local controller to the ground controller immediately upon exiting the runway. The ground controller cannot safely accept aircraft traveling at high speeds unless he is assured that the aircraft can stop before entering other operational taxiways that might be occupied. Hence, runway/taxiway geometry becomes critical to pilot acceptance.

2. As airport utilization increases and aircraft operate at minimum longitudinal separations, the need for additional gate positions becomes evident. It is necessary to ensure that congestion at the gates or on the taxiways does not back up traffic, blocking the exiting system. Pilot acceptance becomes dependent on the adequacy of the number of gates available.

3. The location and design of the high speed runway exit. Simulation efforts indicate that the entrance throats of high speed runway exits may be too narrow and should be redesigned.

4. Adequacy of exit marking and lighting.

5. The surface conditions of the runway and exit.

6. Pilot experience in using high speed exits and familiarity with the airport.

7. Airline operating procedures relative to the use of reverse thrust, brakes and high speed exits.

8. Preferred route to gate position.

9. Motivation to use high speed exit; and

10. Runway and taxiway guidance.

There was considerable discussion in the Topic Group concerning the need for an aid to provide the pilot with the assurance that the runway is clear before he commits himself to a landing. As longitudinal separations are reduced, as runway occupancy time is reduced, the need for such assurance increases. Some form of a cockpit display of traffic information, or cockpit alerting device, may be needed to furnish this assurance to the pilot.

The primary emphasis of research to reduce runway occupancy times has been directed toward landing aircraft. Runways used for both landings and takeoffs may have the additional problem that the time required for the departing aircraft to move into the takeoff position may exceed the time for the arriving aircraft to land and vacate the runway via the high speed exit. This delay will result in an increased in-trail separation when the runway is operated with alternating arrivals and departures. A possible solution is to have the departing aircraft positioned on a high speed entrance ramp. The entrance ramp would be designed so the departing aircraft merges onto the runway before reaching a high speed.

4.5.3 Runway Occupancy Time Conclusions and Recommendations

The Airport Capacity Topic Group concluded:

1. That, even though runway occupancy time is not critical with today's IFR minimum longitudinal separation standards, runway occupancy times will have to be reduced in the future ATC system. Safety, in addition to airport capacity, provides a further motivation for reducing runway occupancy time.

2. That many airports currently have angled exits, but most are used at low speeds or on a sporadic basis. Theoretically, the total runway occupancy time should lie somewhere between 22 and 46 seconds. There is currently little motivation for pilots to use high speed exit taxiways. However with proper motivation, with current exits there is significant potential for reducing runway occupancy time in the short term.

3. That pilot acceptance is essential to the success of any program to reduce Runway Occupancy Time.

4. That consideration should be given to the runway occupancy times of departing aircraft, as well as landing aircraft.

5. That a cockpit display, to assure the pilot that the landing runway is clear, may be required before longitudinal separation standards are substantially reduced.

6. That the potential capacity increases that can be obtained by reducing runway occupancy times at congested airports be determined. This should be performed for both present and proposed in-trail separations, for runways used for arrivals only and for mixed operations.

7. That existing data be evaluated on actual longitudinal touchdown locations and dispersion, aircraft decelleration rates, exits used and exit speeds. Collect data where existing data are inadequate.

8. That the runway occupancy time or times to be used as a design goal be determined. Determine the impact if a percent of the arriving aircraft exceed this design goal.

9. That the technical and operational alternatives available to achieve the design goal be determined. Analyze such options as high speed exit taxiways, runway grooving, drift off areas, dual lane runways, high-speed entrance ramps and staggered dependent dual lane runways for arrivals. In the analyses, factors such as pilot motivation, data acquisition and display, landing, route and taxi guidance requirements, and traffic control procedures should be considered.

10. That the effect of the separation between runways and parallel taxiways on runway occupancy time be investigated.

11. That the FAA expand its present E&D efforts, such as those now underway at NAFEC and Lakehurst, N.J. (NAEC), to fully explore runway surface all-weather friction capabilities as they relate to tire/anti-skid performance characteristics. Provision for high quality surface friction characteristics under all weather conditions is considered essential to minimize runway occupancy time.

4.6 Airport Geometry

4.6.1 General

Communities prefer not to build new airports to serve increases in aviation demand for reasons other than the objections of environmentalists. One of those reasons is the amount of land removed from other (possibly tax producing) land uses. New airports the size of Dallas-Fort Worth Regional Airport and Montreal International Airport (Mirabel) require many thousands of acres the which would be otherwise available for local development.

Using master planning expertise, FAA should develop generalized airport layout plans for new airports that require the minimum of land, recognizing the

need, in some locations, for the provision of noise buffer zones. Innovative ways of arranging the airfield, terminal building, circulation, parking, and access systems and ancillary operations should be assessed in terms of operational feasibility, construction and operation costs and amount of land used.

Not only would such activity be advantageous in reducing land requirements for new airports, but it would provide guidance concerning the modernization and improvement of existing airports that cannot be expanded.

FAA should act as an advocate for new airports by publishing designs for these new airports. These publications will assist local communities to make decisions to provide new airports to deal with increases in aviation activity.

The Topic Group felt that airport planning would be improved if more complete airport air traffic data could be made available to organizations and individuals in industry and in government responsible for airport planning. The data should be collected, organized and formatted so that the needs of the planners are met.

4.6.2 Lateral Separation Between Parallel Runways

As previously stated, one of the major goals of the FAA E&D program should be to reduce the gap between IFR and VFR capacities. This report has discussed the effects of reducing longitudinal separation minima and of improving the accuracy of the delivery of aircraft to the runway threshold on reducing this gap. One other factor warrants consideration. The effect of the spacing of parallel runway centerlines on the gap. Whereas current standards require that under IFR conditions the centerlines of parallel runways be no closer together than 4,300 feet and maintain independence, under VFR conditions independence may be maintained with separations of 2,500 feet (and in some conditions down to 700 feet). For airports with parallel runways separated by less than 4,300 feet, under IFR conditions, the appropriate longitudinal spacings must be applied to arrivals on alternate approaches, or one runway operated for arrivals and the other for departures.

Using the FAA capacity model it can be shown that with parallel runways separated by 2,500 feet we can anticipate an IFR capacity of 59 operations per hour (50% arrivals, 50% departures) while under VFR the capacity would vary from 76 to 104 operations per hour, depending upon the operational strategy utilized. This capacity difference is largely due to the fact that only one arrival stream is permitted under IFR, while two are permitted under VFR.

Reducing the minimum lateral separation standard for parallel runways that may operate independently under IFR becomes an essential program goal. As a

result of previous studies (MITRE Report MTR-6282, "Reduction of Parallel Runway Requirements", January 1973 and Lincoln Laboratory Report ATC-13, "Parallel Approach Surveillance", August 1972) it can be concluded that with surveillance azimuth accuracy of 1 milliradian, a data rate of one second and by reducing the time delay in issuing a missed approach command to three seconds, the minimum theoretical spacing of parallel runways for independent IFR operations would be 2,500 feet. DABS surveillance and DABS data link should be developed to achieve these results. The report of Topic Group 4 (Chapter IV) also discusses this subject.

The Topic Group discussed the possible effects of high precision instrument landing systems (Microwave Landing Systems), improved surveillance, data link and cockpit displays of traffic information on parallel runway spacing. With these advanced air traffic control and air navigation aids, reductions below current lateral separation minima are feasible. With reduced lateral separation it is questionable that a monitor controller can detect and warn the pilot of an intruder in sufficient time to assure safe avoidance. The Topic Group is of the opinion that some form of a cockpit display of essential traffic and/or automatic warning of an intruder may be needed to obtain pilot acceptance of reduced runway separation standards for simultaneous independent parallel approaches.

The Topic Group recognized that the capability of M&S to provide and monitor an appropriate stagger between arrival streams approaching closely spaced parallel runways may provide significant capacity increases at some high density airports. The Group felt that this potential for capacity increase should be studied further.

4.6.3 Airport/Airway Interactions

Do terminal ATC procedures present a major capacity problem or rather is it the present airport configuration which causes the greatest capacity loss; or is it a combination of both of these factors? It appears that it is the interaction of these factors that create the problem. An integrated analysis of airspace and airfield problems, on an airport site-specifc basis, will yield many benefits, including the establishment of E&D requirements. An integrated analysis can identify critical problems in the airspace and assess the capability of existing and potential E&D products to solve these critical problems. Such analyses will produce an assessment of the benefits of airspace reconfiguration, reduced controller workload, improved airfield utilization, and other operational gains.

Each major terminal airspace should be subjected to an integrated airspace/airfield analysis on a scheduled basis. Airspace is becoming more and more of a premium commodity and by making this periodic review a requirement, the FAA would then be able to focus attention on areas where capacity gains could be achieved through modifications or changes.

The Topic Group is of the opinion that terminal air traffic control problems and their solutions are often site-specific in nature. E&D efforts may well develop some general principles of design that can be applied nationally, however, it is felt that site specific analyses, simulations and operational experimentation and test will produce the most effective solutions to the terminal area problem.

4.6.3.1 Commuter, Helicopter and Small Aircraft Requirements

Commuter, helicopter and small aircraft operations at major airports are currently growing at a rapid rate. For example, the annual growth rate for commuter aircraft operations at Denver's Stapleton International Airport is currently on the order of 50% a year. Growth in this segment of aviation may lead to severe airport congestion and safety problems at many high density airports.

Much of the safety and congestion concerns arise from the mixing of aircraft of different performance characteristics at the large airports. Small aircraft with low speeds and high susceptibility to wake turbulence often use the same airspace and airfield facilities as large aircraft with high speeds and different separation requirements. To the extent possible, the FAA should follow a program designed to segregate the different classes of aviation traffic at the major airports. The segregation should take place both in the airspace and on the airfield.

Segregation of these classes of aviation at the major airports will require the construction of light aircraft strips parallel to the major runways, the construction of dedicated landing areas for rotary wing aircraft, the development of advanced air navigation and air traffic control aids and the development of innovative air traffic control procedures to make better use of the surrounding airspace.

The light aircraft strips and the helicopter pads can do little to increase airport capacity unless independent procedures, that is, procedures which provide independence in the approach, departure and missed approach airspace for heavy jet aircraft from the airspace provided for light and rotary wing aircraft, are developed. Independent procedures are practical to a limited degree today. Rotary wing point-in-space clearances (that is clearances to geographical points rather than to specified electronic fixes), and RNAV routes are already in existence and it appears that they may provide insights into more innovative procedures.

The implementation of optimum descents from cruise procedures, sometimes referred to as Profile Descents, should free up additional low altitudes in the terminal area. These low altitudes may well be used to provide for independent approach procedures - particularly for light and rotary wing aircraft. At high traffic density airports with a mix of heavies, lights and rotarcrafts, the air traffic controllers will require an improved system of surveillance of the airport surface.

The surveillance system should be equipped with automatic identification and tracking capabilities. The requirement for the airport surface surveillance system increases as traffic and runway system complexity increases. The capability of RNAV and MLS to provide curved approaches and the potential use of M&S to provide and monitor an appropriate stagger between arrival streams on parallel or intersecting runways are tools which may provide significant increases in airport capacity. E&D efforts in the form of simulations is required to determine quantitatively the increases in capacity that can be achieved, at specific locations, through the utilization of advanced ATC techniques.

4.6.3.2 Precision Missed Approach Procedures

At the present time there are sets of parallel runways at major urban area airports that cannot be used for simultaneous instrument approaches because missed approach procedures cause conflicts in the use of the airspace. For example, simultaneous parallel approaches to runways 31L/R at JFK are not now permitted because current missed approach and departure procedures, particularly from 31R, would cause interference with LGA airspace. By utilizing the curved (segmented) course capabilities of MLS, a precision guidance system for departure or missed approach navigational guidance could be provided to take the traffic away from the airspace in which conflict may occur.

By changing these parallel runways from use as dual lane runways to independent parallels, the MLS missed approach guidance can make a significant contribution to increasing airport capacity at selected locations.

Interim Report - Task 1 of Economics & Science Planning, Inc. "The Influence of Present E&D Programs on Airport Capacity" dated July 3, 1978 (Appendix B) indicates that by using precision missed approach guidance, staggered arrivals on intersecting runways and improved surveillance, substantial increases in airport capacity - at selected airports - can be achieved even with today's separation standards. Theoretical analyses, described in the appendix, predict that it may be possible through these techniques to increase the IFR capacity at JFK by 50% and 25% at ORD. The investigation was limited to JFK and ORD, however, the techniques may be applicable at other high traffic density airports. Investigations should be initiated to determine whether or not these techniques can produce capacity increases at other airports.

4.6.4 Airport Geometry Conclusions and Recommendations

The Airport Capacity Topic Group determined:

1. That the development of generalized airport layout plans for new airports that will require a minimum of land, may encourage the construction

of new airports and will provide guidance for improving existing land constrained airports. Therefore, more efficient schemes for new airports should be developed.

2. That the design goals of the FAA DABS Surveillance and Data Link Development Program should be a surveillance azimuth accuracy of 1 MR, a data rate of one second and the capability of reducing the time delay in issuing a missed approach command to three seconds where required to reduce lateral spacing standard for parallel runways.

3. That a cockpit display, designed to monitor parallel approaches, may increase airport capacity by assuring that minimum safe separation standards will be maintained during simultaneous independent approaches to parallel runways with reduced lateral spacing. Therefore a cockpit display to monitor parallel approaches should be evaluated.

4. That M&S capabilities to provide and monitor staggered arrival streams approaching closely spaced parallels, may increase airport capacity. Therefore these additional M&S capabilities should be investigated.

5. That the FAA expedite the development of an improved airport surface surveillance system detecting aircraft on and near the surface of the airport with automated identify and tracking functions.

6. That the curved approach capabilities of MLS and RNAV may assist in the development of independent terminal approach procedures.

7. That FAA develop and execute a plan for the collection and distribution of airport air traffic data in a format that would make the data useful for airport planning.

8. That FAA develop the capability to perform periodic integrated airfield/airspace analyses, at major urban areas, on a site specific basis.

9. That FAA design, test and demonstrate the capability of developing independent procedures, utilizing aids such as RNAV and point-in-space procedures, to and from a short runway at a major or reliever airport. JFK runway 14/32 might make a good test site.

10. That the feasibility of relaxing current standards concerning multiple occupancy of runways be investigated.

11. That the feasibility and desirability of independent or segregated procedures on separate runways at airports with a large number of heavy operations be determined and demonstrated.

12. That the minimum acceptable longitudinal separations between approaches to dependent parallel runways be determined.

13. That an E&D effort toward studying the feasibility of using precision missed approach procedures to increase airport capacity be initiated. (See Appendix B.)

14. That ways for exploiting MLS to enhance airport capacity be determined.

5. VORTEX AND NOISE LIMITATIONS TO AIRPORT CAPACITY

5.1 General

Wake Vortex Turbulence and Aircraft Noise are two consequences of aircraft flight that have major effects on airport capacity. Wake Vortex Turbulence and Aircraft Noise not only adversely affect the potentials of increasing airport capacity but are at many airports making it difficult - if not impossible - to retain air operations at current levels. The adverse effects of these phenomena may be alleviated, to some extent, through the use of operational techniques and procedures and through the development and implementation of aircraft modifications and ground based systems. Unless these adverse effects can be substantially reduced, air transportation's future growth potentials will be seriously restricted.

5.2 Wake Vortex Turbulence

All aircraft generate trailing wake vortices, but it has only been since the introduction of wide-bodies jets (B-747, DC-10 and L-1011) into the air carrier fleet that the phenomenon of aircraft wake vortices has assumed operational significance. The vortices from these large aircraft can present a severe hazard to other aircraft which inadvertently encounter the vortices; the following aircraft may be subjected to rolling moments which exceed the aircraft roll control authority, a dangerous loss of altitude, engine damage and to possible structural failure.

Landing aircraft, before 1970, maintained a minimum of 3 nautical-mile separation under Instrument Flight Rule (IFR) conditions. In March 1970, the separation standards behind the heavy jets (a heavy jet is defined as an aircraft which has a maximum certified take-off weight in excess of 300,000 pounds) was increased by FAA to 4 nautical-miles for a following heavy aircraft and to 5 nautical-miles for a following non-heavy aircraft. In November 1975 the standards were further increased to 6 miles for an aircraft with a maximum certificated take-off weight less than 12,500 pounds following a heavy.

Reductions in separation standards are limited by the wake vortex phenomenon. Aircraft wake vortices and the separation standards required to avoid aircraft upset tend to cancel out the potential gains from the major FAA E&D efforts which were geared to increasing system capacity.

As the percentage of heavies in the aircraft mix increases, the loss of airport capacity increases. At the eight major airports that have been subjects of special Task Force efforts it was found that the capacity loss due to the increasing number

of heavy aircraft varies with location and meteorological conditions and may be expected to be as much as 17% if present day separation standards cannot be reduced.

Topic Group 2 examined the three ongoing E&D activities launched to minimize the adverse system effects of aircraft wake vortices. These programs are:

1. Vortex Advisory System (VAS)
2. Wake Vortex Avoidance System (WVAS)
3. Vortex Alleviation

5.2.1 Vortex Advisory System (VAS)

The goal of the Vortex Advisory System is to provide information on the presence or absence of potentially hazardous vortices. The information will be provided to the air traffic controllers and will permit reduced separations to be implemented whenever vortices are determined to be innocuous. The VAS concept is predicated on the observation that current separation standards are overly conservative most of the time because the prevalent meteorological conditions cause vortices to dissipate or move out of the flight path of the following aircraft in a short period of time. Analysis of the extensive data available on vortex behavior as a function of meteorological conditions indicates that there are wind conditions which predictably remove vortices. A wind rose criterion could, therefore, be used to determine when the separation could be uniformly reduced to 3 nautical-miles for all aircraft types rather than using the 3, 4, 5, and 6 mile separations currently required.

An analysis of the U.S. airports indicates that meteorological conditions are such that wake vortices will quickly dissipate between 20 and 79% of the time.

The VAS at O'Hare consists of a network of seven meteorological towers, each instrumented at the 50 foot and at the 47 foot levels with wind magnitude and direction sensors. The towers transmit the wind data to a centrally located processor which determines the vortex conditions in the approach corridor and displays the appropriate interarrival separation to the air traffic controllers. Separation requirement determination is made through the use of an elliptical VAS algorithm, with the major axis parallel to the runway centerline. If the actual wind vector is within the ellipse, the condition is RED and the 3, 4, 5 and 6 miles separations apply. If the wind vector is outside of the ellipse, the condition is GREEN and most aircraft may be separated by three miles.

To demonstrate the possible capacity gains of VAS and to assess the impact of VAS on controller workload, a simulation was conducted of air operations within

the Chicago O'Hare International Airport terminal environment. This simulation has been concluded and the major findings were that there were no procedural implications that would preclude the operational implementation of VAS at O'Hare and that significant capacity increases can be obtained.

In order to determine whether vortex behavior in the middle marker to runway threshold region could be applied in the outer marker to middle marker region, a test program to track vortices in free air between the outer and middle marker was established. The test program has suffered numerous delays due primarily to tracking equipment problems. It is, however, anticipated that adequate tracking equipment will result in test completion by April 1, 1979.

In the development of the VAS, primary consideration was given to its operational application in the arrival mode. However, wake vortices are creating a capacity restraint on departing aircraft. Departure time separation standards currently in use require 120 second interval between a heavy and a non-heavy, a 90 second interval between a heavy and a heavy, and a 60 second interval behind a non-heavy departure. If the VAS concept can be applied to departures, then during the GREEN conditions a 60 second interval could be used between all departing aircraft. A joint FAA-Canadian Ministry of Transportation (MOT) project at Toronto International Airport was the initial research effort for expanding VAS applicability to departures. Preliminary research assessing the behavior of vortices generated by departing aircraft has indicated that it is feasible to pursue the development of a wind criterion algorithm to be used for establishing departure intervals. Further data collection and analysis efforts will be required to establish the statistical validity of VAS separations for departures. All operational safety factors must be thoroughly analyzed before current departure standards may be decreased.

5.2.1.1 VAS Conclusions and Recommendations

The Airport Capacity Topic Group determined:

1. That VAS offers the best near-term hope of recovering some of the airport capacity losses attributable to wake vortices, and that there are no procedural implications which should preclude the operational implementation of VAS. The benefits of VAS are, however, realizable only under wind conditions which predictably remove the vortices.

2. That before operational implementation of VAS can be achieved, FAA, through demonstration programs, needs to assure the aviation industry that under certain meteorological conditions, VAS can reduce current separation standards without adversely affecting safety.

3. That the 14 knot by 7 knot elliptical VAS algorithm used to determine approach separation requirements appears to be satisfactory based on test data compiled to date. Research activity should be continued in an attempt to increase the airport capacity benefits of VAS through modification of the algorithm.

4. That the completion of the VAS test program to track vortices in free air between Middle and Outer Markers, now underway at O'Hare be expedited. As soon as the test program is completed a Technical Data Package to assist the FAA Operating Services in the acquisition, deployment and operation of VAS at high traffic density airports be expedited.

5. That VAS wind criterion algorithms to be used for establishing departure intervals be developed and statistically validated to determine the operational safety factors involved in decreasing the current departure standards. The implementation of the basic VAS should not await the completion of this investigation.

6. That, as a matter of priority, the extension of VAS capability beyond the outer marker be investigated.

7. That a determination be made as to the wake vortex effects on approaches to parallel runways spaced less than 2,500 feet apart.

8. That consideration be given to providing an electronic alerting system in the cockpit to advise the pilot as to the VAS system status (RED or GREEN).

5.2.2 Wake Vortex Avoidance System (WVAS)

Although the VAS has the potential to increase airport capacity it will do so only under specified meteorological conditions. During the summer months, when low winds prevail, a reduction in separation can only be achieved about 20% of the time. A more complete solution to the wake vortex problem would be the development of a full Wake Vortex Avoidance System.

The WVAS is a system which utilize meteorological and sensor data to detect, track and predict vortex motion and decay. Using WVAS, wind direction and speed are automatically sensed, combined with active vortex sensor data in a digital computer-processor and then input to the Automated Radar Terminal System metering and spacing algorithm, or displayed for the controller, where it is used to determine metering and spacing commands. A combined output is then used to subsequently control aircraft and departure separations.

In the February 1977 report of the Transportation Systems Center, "Aircraft Wake Vortices: A State of the Art Review of the United States R&D Program", it was concluded that the tens of thousands of vortex tracks that were collected and analyzed by TSC indicate that with a system meeting the design goals of WVAS, 3-mile separation between aircraft of any type could be used safely 99% of the time and that a WVAS could allow down to 2-mile separation 86% of the time.

Conceptually, in the WVAS, the predictive model receives aircraft type and sequence data from the ARTS computer and meteorological data from the sensors whenever the approach controller or metering and spacing system requests terminal approach spacing for a specific aircraft. The predictive model, based on these inputs, would determine the minimum spacing for the following aircraft and provide that output to the M&S computer or the controller. The separation criteria provided would be purely predictive at this point. As the aircraft nears the final approach path, the vortex sensors would detect and track the vortices from the aircraft preceding the aircraft of concern. Vortex strength and vortex position as a function of time relative to the lead aircraft would be monitored by the sensing subsystem. The rate of motion of the vortex from the vortex tracker and the rate of decay of the vortex would be inputs to an algorithm to determine when the approach corridor would be clear relative to the avoidance of the vortex shed by the lead aircraft. The controller or the M&S system could compare this time with the time of arrival of the aircraft of concern over the middle marker to determine if corrective action is necessary. In the interim, the vortex position and decay as a function of time would have been fed back to the predictive model as an updating input. The actual vortex behavior would then be compared in the model with the predicted behavior to determine if any update or correction is necessary, thus providing a completely automated closed-loop system for providing positive vortex avoidance.

The Topic Group sensed that there was no great management pressure to force early completion of the WVAS program. The resources - manpower and money - allocated to the program, reflects a determination that the program lacks priority. Since the effective utilization of WVAS might well be dependent on the prior development of other components of the National Airspace System - such as M&S - management may have concluded that the WVAS program could well proceed at a moderate rate.

Although considerable time has been spent in efforts to develop a WVAS, the Topic Group had to conclude that all that exists today is a rather loosely stated system concept. Considerable work needs to be done to check the feasibility and operational suitability of components, the integration of the components into a system, the shakedown of the software and the safety of the system.

5.2.2.1 MLS as a Vortex Avoidance Device

The Topic Group discussed the utilization of MLS components for vortex avoidance. At its last meeting two papers[1/] were presented to the Group. These papers explore, in a preliminary fashion, the potential role that MLS may play in the trailing vortex avoidance problem. The general concept, explored in the papers, is that through the use of MLS components glide paths may be provided such that the "following" aircraft would never fly below the path of the lead aircraft and therefore would not be adversely affected by the lead aircaft's wake vortices. It appears that the potential benefits of the proposed concept are comparable to VAS. Both papers conclude that there is sufficient promise in the use of MLS for vortex avoidance to justify further investigation and study.

Even though the Topic Group did not have adequate time to study the concept in detail, the Group did conclude that FAA should be encouraged to study the problem further and make detailed analyses and a thorough evaluation of the concept.

5.2.2.2 WVAS Conclusions and Recommendations

The Airport Capacity Topic Group determined:

1. That, premised on an ultimate operational requirement of a minimum longitudinal spacing of 2 nautical miles, a total system design for a WVAS should be immediately developed. Efforts toward the selection of a practical, operationally reliable vortex sensor be accelerated. The preliminary WVAS Prediction Model should be refined, validated and adapted to an operational configuration.

2. That the adaptive separations output of the WVAS will be continously changed, dependent upon traffic demand and meteorological conditions, and controllers may not be able to use these adaptive separations for the maximum efficiency of the system. Therefore it appears that the full capacity of WVAS will depend upon the prior implementation of M&S. The WVAS separation requirement output would then go directly to the M&S system.

3. That a determination as to the benefits that may be realized through the use of a WVAS without an M&S interface be made.

4. That the FAA should undertake further studies to determine the possible roles of MLS and RNAV for wake vortex avoidance. The FAA should also make detailed analyses and a thorough evaluation of the dual MLS glide path concept for wake vortex avoidance.

[1/] "MLS Wake Turbulance Avoidance Configuration", Bendix Communications Division Internal Memorandum MLS-ICAO-078, January 1979; "Preliminary Analysis of the Use of Two Glide Slopes at Runways with Existing Glide Slopes of Less Than 3°", MITRE Memorandum W47-M1139, January 1979.

5.2.3 Vortex Alleviation at the Source

The ultimate solution to the wake vortex problem might well be the eventual alleviation of trailing vortices at the source. Aircraft aerodynamic modification has the potential for breaking up or minimizing the vortex more rapidly and thus providing improved safety and increased capacity. The National Aeronautics and Space Administration (NASA) has responded to the FAA request to participate actively in solving the wake vortex problem for the past eight years. However this work is now coming to a close.

Aerodynamic alleviation is achieved by modification of the spanwise wing loading or by the generation of turbulence behind the generating aircraft, or by a combination of these two methods. Flight test programs indicate that a limited amount of aerodynamic alleviation is possible with some adverse effects during landing approach.

Even though it recognizes that trade-offs or penalties may have to be paid to gain the reduction in vortex strengths desired, and engineering problems may be so complex that alleviation may not be cost-effective, the Topic Group most enthusiastically supports and recommends high priority for continued research in this area. Trailing vortices may not be able to be eliminated but the adverse effects may well be reduced through aerodynamic alleviation. Further experimentation, analyses, wind tunnel and flight tests are required to answer existing questions, develop techniques and to demonstrate the validity of the concept as applied to existing aircraft. New techniques should be developed for incorporation into new aircraft, to reduce the adverse effects of trailing vortices while at the same time reducing the penalties of aerodynamic alleviation.

There is considerable promise that through combined industry/government E&D activity, aerodynamic alleviation may result so as to permit 3 mile landing separation behind any swept wing turbine powered aircraft modified for vortex attenuation in the landing configuration.

The Topic Group believes that even though aerodynamic alleviation would increase fuel costs (the additional fuel cost is estimated to be about $4.50 per aircraft per landing) the reduction in final approach spacing resulting from aerodynamic alleviation would result in a net savings in fuel costs per landing.

Wind tunnel and flight test experimentation is expensive. NASA must be convinced by FAA that NASA's activities are essential to the future of air transportation, that FAA will actively participate in the program and that FAA will to some degree participate in program funding.

5.2.3.1 Vortex Alleviation Conclusions and Recommendations

The Airport Capacity Topic Group determined:

1. That some vortex alleviation may be obtained through modifications of spanwise wing loading and by the generation of turbulence behind the generating aircraft. Solutions to the wake vortex problem must be cost-effective, fuel efficient and safe.

2. That aerodynamic alleviation may result in some adverse effects in the economic, operational and environmental characteristics of flight operations. However, aerodynamic alleviation has a great potential for fuel conservation by reducing in-trail final approach spacing.

3. That through continued research there is a promise of the development of an economically feasible, operationally desirable and environmentally acceptable aerodynamic vortex alleviation aircraft modification.

4. That joint FAA/NASA wake vortex alleviation research funding levels should be increased and the work accelerated. FAA should encourage the aircraft manufacturers and the airlines to participate actively in this research program.

5. That techniques developed through experimentation, analyses, wind tunnel and flight tests, should be applied to existing aircraft, if cost-effective, and that continued research for new techniques to reduce the penalties of aerodynamic alleviation should be supported. The feasibility and cost of introducing these new techniques into the design of new aircraft should be investigated. Concurrent with the development of the aircraft modifications required to alleviate vortex effects at the source, the FAA should determine the aircraft certification and operational procedure changes needed.

5.3 Aircraft Noise*

Similar to the wake vortex problem, aircraft noise has been with us since the first powered flight. However, it was not until the early 1950s that protests and threats of legal or political action against noise became quite noticeable. With the introduction of turbine power aircraft into the civil air transport fleet, air travel grew at a phenomenal rate and communities located in the vicinity of airports soon began to display increasing annoyance with jet aircraft noise. As the frequency of operations increased, as an increasing number of airports started to receive jet service, as heavier aircraft were put into operation, and as the urban development around airports increased, the aircraft noise problem grew in importance.

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*See Appendix C to Chapter III for further information received by the Topic Group relative to Aircraft Noise.

Obviously, it is in the public interest to reduce aircraft noise to as low a level as possible. This reduction might be achieved by reducing the source noise, by moving the source noise further away from people and by moving people away from the noise. However, it is also in the public interest to adopt all improvements - such as increased airport capacity - that will provide safer, faster and more economical air transportation. It is beneficial to the general welfare of the nation to achieve maximum capacity from each airport in the air transportation system since, without this, the nation's resources allocated to air transportation will not be optimized. Clearly there is a direct conflict between reducing aircraft noise and increasing airport capacity.

The simple, direct and effective solution to the airport capacity problem is to create additional airport capacity by constructing additional airports in areas of high forecast demand and by expanding existing airports that are approaching saturation. Simple solutions are not always simple to implement. In the past two decades, environmental opposition to the construction of new airports in major metropolitan areas and the expansion of high traffic density airports, has grown strong and powerful. In earlier days of aviation, municipalities actively sought new airports and competed for air services. Today, the airport is no longer considered a good or desirable neighbor. Aircraft noise has become a more serious deterrent to providing the needed airport capacity. To reduce noise, curfews and operational procedures have been established at some airports which restrict airport usage.

Noise abatement procedures - procedures which reduce the source noise-level and move the source noise further away from people - have been developed. FAA is developing an Advisory Circular setting forth standardized noise abatement procedures for jet aircraft in excess of 75,000 pounds. These procedures should lessen the noise impact and might reduce opposition to airport growth.

The Topic Group found that airport planning was handicapped by the lack of adequate means of determining noise levels that would be considered as "tolerable" or "acceptable". Current measurement techniques - NEF - do not measure aviation's contributions to the total (ambient and aviation) noise. A national standard noise measurement technique would provide airport and urban planners with a common understanding of the noise problem.

Changes in operational techniques and noise abatement procedures have been incorporated into the system to reduce the adverse effects of aircraft noise. The introduction of high by-pass ratio engines has made a significant contribution to reducing aircraft noise. FAR 36 has made its contribution to the environment - but still public opinion has not changed. Technology offers promises of further noise reductions. In order to encourage aviation to continue its efforts to reduce the adverse effects of aircraft noise, a reward system should be established which would relate aircraft noise reductions made over a period of time with permissible

increases in airport capacity. This would permit air transportation growth while at the same time reducing or stabilizing aircraft noise impacts on the community.

Although it is recognized that FAA has sponsored and funded numerous compatible land-use programs, the Topic Group felt that additional emphasis should be placed on programs to encourage local jurisdictions to zone areas around the airport for compatible land use, thus minimizing the impact of aircraft noise.

Whenever the public, for whatever reason (altered flight procedures, development adjacent to an arrival/departure course, etc.), is placed in closer proximity to sources of aircraft noise, an increasingly adverse reaction by the public is assured. Any change in FAR Part 77.25, Civil Airport Imaginary Surfaces, which would effectively raise these surfaces, by revision to the existing rule, would reduce the present buffer between aircraft and man-made structures - homes, apartment buildings, office buildings - and further aggravate an already critical airport/community noise situation.

Technological advances have been made toward the development of quieter aircraft, and noise abatement procedures have been adopted. To gain the benefits that are inherent in these advances, FAA should inaugurate a concentrated public information program, calling attention to the giant strides that have been taken in reducing aircraft noise, assuring the public that positive actions are being taken to protect the environment, emphasizing the many benefits the public derives from the airport and stressing that airports are vital to our national economy and national welfare.

5.3.1 Aircraft Noise Conclusions and Recommendations

The Airport Capacity Topic Group determined:

1. That reaction to aircraft noise has a detrimental effect on airport capacity.

2. That actions of environmentalists have reduced the capability of local governments to provide the additional airport capacity required to accommodate air transportation forecasted growth.

3. That in spite of efforts to reduce the impact of aircraft noise, pressure groups oppose the construction of new airports or the expansion of existing airports.

4. That programs for increasing airport capacity may not be viable in light of the growing environmental pressure to stablize or even reduce the number of operations at many major airports.

5. That the FAA take the lead in establishing a national standard noise metric for aviation planning. This would ensure maximum compatibility with noise impact studies conducted in other environmental areas, and would allow for planning that accounts for the effects of population annoyance and ambient noise effects. This action should be followed by the establishment, in conjunction with user groups and other interested agencies and parties, of baseline acceptable noise level criteria for various types of aviation activities and land uses.

6. That planning criteria be developed that relate airport noise reduction, over a period of time, to additional airport capacity while at the same time reducing or stabilizing airport noise impacts on the community.

7. That the FAA strongly encourage local jurisdictions to rezone adjacent noise impacted areas for compatible land use.

8. That FAA should vigorously resist any alteration of FAR Part 77.25, Civil Airport Imaginary Surfaces, that would effectively raise any of the surfaces as they exist today.

6. LANDSIDE RESTRICTIONS

6.1 General

The mission of an airport is to serve as a modal interchange point for air travelers and as a service point for aircraft. The landside has been defined as the area bounded by the points at which passengers and cargo enters the airport proper, whether by transit modes, private automobiles, or other means, to the point on the apron at which the passenger actually enters the aircraft, mobile lounge or other means of transporting the passenger to the aircraft. The landside, therefore, includes the access roads and ramps, parking facilities, terminal curbside, terminal facilities, and that part of the apron around the airplane used to service the passengers.

Numerous manuals, advisory circulars and standards have been developed and published by the Federal Aviation Administration. The Topic Group reviewed FAA's more recent activities concerning airport landside problems. Efforts such as the development of Terminal Building Design Criteria were discussed in detail. The mechanisms used by FAA to make its E&D end products available to the public through the publication of manuals and advisory circulars was described to the Group. These efforts, the Group found, were useful and appreciated by the industry.

The Topic Group reviewed the status of an ongoing FAA E&D program for the development of a simulation model, which will take a person, baggage or cargo from the airport landside boundary to the aircraft gate. This model should be able to forecast, and assist in the analysis of bottlenecks in the normal flow of traffic through the landside portion of the airport. The model development is completed and the model is being validated. The FAA is preparing a handbook on the use of the model.

6.2 The Landside Problem

The Topic Group agreed that the access roads and airport terminal buildings could well be potential constraining factors in increasing airport capacity. Since airport access roads usually extend well beyond the airport boundaries, airport authorities generally lack direct responsibility for planning, building and operating these roads. This raises the question as to whether future airport needs for access are being sufficiently considered in most planning environments.

The technology to resolve the landside problems, for the most part, already exists. However, multijurisdictions over airports through the control of airport

ground access routes, land areas impacted by airport noise, taxing powers and other factors makes it difficult and sometimes impossible to apply this technology. Better coordination of multijurisdictional -- Federal, state and local governmental responsibilities for airports and their environs would provide a substantial degree of relief.

The availability of funds for airport access roads was the subject of considerable Group discussion. It was concluded that the urgency of the requirements for increased airport access road capacity has not been convincingly made known to the highway planners at either the Federal or state levels. To date, in the contest for Federal funds, airport access roads have come in a poor second. Aviation's needs -- needs backed by data -- are not known.

Many of the airport landside problems are the responsibilities of the Airport Operators or the airport tenants, and are in no way the responsibility of the FAA. The FAA, the Topic Group believes, should not involve itself in problems that could best be resolved through normal landlord/tenant relations and negotiations between the airlines and the airport authorities.

6.3 Conclusions:

The Airport Capacity Topic Group concluded: That the FAA should limit its E&D activities in the airport landside area, to those activities required for the development of FAA standards, manuals and advisory circulars.

7. SUMMARY OF RECOMMENDATIONS

The Airport Capacity Topic Group recommended:

1. That the planning and execution of the total airport system E&D program be concentrated in a single organizational entity within the FAA E&D structure whose sole responsibility is this program.

2. That the FAA develop a plan for determining how the total advanced terminal system (both airborne and ground-based) would be operationally utilized, and to develop the capability to test, evaluate and demonstrate the effectiveness of the system.

3. That airport site specific elements be identified and considered in the development of E&D requirements.

4. That the development of M&S be pursued as a matter of priority, with the intent that it would be the basic component of the future terminal area air traffic control system.

5. That the completion of the Basic Arrival M&S System simulation, live flight verification tests and field appraisal in various weather and runway conditions and under normal operating environment be expedited. In this regard, it is essential that a plan for field appraisal be developed and approved as soon as possible. The field test may be conducted at a low density ARTS III site of minimal terminal area complexity.

6. That action toward the development of an implementable M&S capability be initiated as soon as possible. Additional simulation work will be required and should include a determination of missed approach rates, for example, as well as efforts to integrate M&S with terminal area flow management.

7. That before a national implementation program for M&S is launched, a technical analysis of the field trials should be made to determine the quantitative improvement of delivery precision made by the addition of M&S to the present manual system.

8. That close coordination between En Route and Terminal Area M&S development programs be accomplished to assure the two-way effectiveness of the interface between these systems.

9. That an investigation be made to determine the advantages of expanding the area of coverage of the Terminal M&S System.

10. That expansion of the arrival only M&S to provide for departure metering and sequencing servicing be accomplished so that this feature may be phased into the air traffic control system as soon as possible.

11. That concepts and procedures necessary to use advanced airborne systems -- such as 4D RNAV, MLS, CDTI, etc. -- and capabilities effectively in an M&S environment be investigated and determined.

12. That the FAA undertake an in-depth study, including simulation and flight test, of cockpit located displays of traffic information to determine:

   a. Its value to improve the accuracy of aircraft delivery time when used in conjunction with M&S;

   b. Its need to provide pilot assurances of safe separation and a clear runway; and

   c. Its application and need to monitor approaches to closely spaced parallel runways.

13. That M&S modifications be determined and developed to:

   a. Accommodate efficiently fuel conservative profile descents;

   b. Realize maximum advantage of DABS data link; and

   c. Interface and integrate effectively M&S with VAS and WVAS.

14. That both 4D RNAV and CDTI techniques be explored and tested so that the best of each technique might possibly be integrated into the future ATC system.

15. That the FAA assess the effect of weather anomalies on the ATC system and make a value analysis of the contributions made by improved weather information on the ATC system. FAA should then develop those improved weather detection and display techniques for the terminal controller deemed effective.

16. That the FAA require an operating airport rotating beacon at every airport with a published instrument approach procedure.

17. That, due to the potential of reducing delays and increasing capacity, the FAA should evaluate class sequencing further, identify the benefits to be obtained and if found operationally feasible, develop a procedure to implement the sequencing mechanism as part of the M&S expansion program.

18. That a VASI system should be installed on every runway authorized for use by turbine-powered aircraft whenever that runway is not equipped with an electronic glide slope.

19. That the potential capacity increases that can be obtained by reducing runway occupancy times at congested airports be determined. This should be performed for both present and proposed in-trail separations, for runways used for arrivals only and for mixed operations.

20. That existing data be evaluated on actual longitudinal touchdown locations and dispersion, aircraft decelleration rates, exits used and exit speeds. Collect data where existing data are inadequate.

21. That the runway occupancy time or times to be used as a design goal be determined. Determine the impact if a percent of the arriving aircraft exceed this design goal.

22. That the technical and operational alternatives available to achieve the design goal for runway occupancy time be determined. Analyze such options as high speed exit taxiways, runway grooving, drift off areas, dual lane runways, high-speed entrance ramps and staggered dependent dual lane runways for arrivals. In the analyses, factors such as pilot motivation, data acquisition and display, landing, route and taxi guidance requirements, and traffic control procedures should be considered.

23. That the effect of the separation between runways and parallel taxiways on runway occupancy time be investigated.

24. That the FAA expand its present E&D efforts, such as those now underway at NAFEC and Lakehurst, N.J. (NAEC), to fully explore runway surface all-weather friction capabilities as they relate to tire/anti-skid performance characteristics. Provision for high quality surface friction characteristics under all weather conditions is considered essential to minimize runway occupancy time.

25. That the development of generalized airport layout plans for new airports that will require a minimum of land, may encourage the construction of new airports and will provide guidance for improving existing land constrained airports. Therefore, more efficient schemes for new airports should be developed.

26. That the design goals of the FAA DABS Surveillance and Data Link Development Program should be a surveillance azimuth accuracy of 1 MR, a data rate of 1 second and the capability of reducing the time delay in issuing a missed approach command to 3 seconds where required to reduce lateral spacing standard for parallel runways.

27. That M&S capabilities to provide and monitor staggered arrival streams approaching closely spaced parallels, may increase airport capacity. Therefore these additional M&S capabilities should be investigated.

28. That the FAA expedite the development of an improved airport surface surveillance system detecting aircraft on and near the surface of the airport with automated identify and tracking functions.

29. That FAA develop and execute a plan for the collection and distribution of airport air traffic data in a format that would make the data useful for airport planning.

30. That FAA develop the capability to perform periodic integrated airfield/airspace analyses, at major urban areas, on a site specific basis.

31. That FAA design, test and demonstrate the capability of developing independent procedures, utilizing aids such as RNAV and point-in-space clearances, to and from a short runway at a major or reliever airport. JFK runway 14/32 might make a good test site.

32. That the feasibility of relaxing current standards concerning multiple occupancy of runways be investigated.

33. That the feasibility and desirability of independent or segregated procedure on separate runways at airports with a large number of heavy operations be determined and demonstrated.

34. That the minimum acceptable longitudinal separations between approaches to dependent parallel runways be determined.

35. That an E&D effort toward studying the feasibility of using precision missed approach procedures to increase airport capacity be initiated. (See Appendix B.)

36. That the MLS, and MLS coupled with M&S, WVAS and other advanced systems, be evaluated as a potential for increasing capacity through path shortening, reducing common approach paths, reducing lateral spacing, etc.

37. That the completion of the VAS test program to track vortices in free air between Middle and Outer Markers, now underway at O'Hare be expedited. As soon as the test program is completed a Technical Data Package to assist the FAA Operating Services in the acquisition, deployment and operation of VAS at high traffic density airports should be prepared.

38. That VAS wind criterion algorithms to be used for establishing departure intervals be developed and statistically validated to determine the operational safety factors involved in decreasing the current departure standards. The implementation of the basic VAS should not await the completion of this investigation.

39. That as a matter of priority, the extension of VAS capability beyond the outer marker be investigated.

40. That a determination be made as to the wake vortex effects on approaches to parallel runways spaced less than 2,500 feet apart.

41. That vortex research activity be continued in an attempt to increase the airport capacity benefits of VAS through modifications of the current VAS elliptical algorithm.

42. That consideration be given to providing an electronic alerting system in the cockpit to advise the pilot as to the VAS system status (RED or GREEN).

43. That, premised on an ultimate operational requirement of a minimum longitudinal spacing of 2 nautical miles, a total system design for a WVAS should be immediately developed. Efforts toward the selection of a practical, operationally reliable vortex sensor be accelerated. The preliminary WVAS Prediction Model should be refined, validated and adapted to an operational configuration.

44. That a determination as to the benefits that may be realized through the use of a WVAS without an M&S interface be made.

45. That the FAA should undertake further studies to determine the possible roles of MLS and RNAV for wake vortex avoidance. The FAA should also make detailed analyses and a thorough evaluation of the dual MLS glide path concept for wake vortex avoidance.

46. That joint FAA/NASA wake vortex alleviation research funding levels should be increased and the work accelerated. FAA should encourage the aircraft manufacturers and the airlines to participate actively in this research program.

47. That techniques developed through experimentation, analyses, wind tunnel and flight tests, should be applied to existing aircraft, if cost-effective, and that continued research for new techniques to reduce the penalties of aerodynamic alleviation should be supported. The feasibility and cost of introducing these new techniques into the design of new aircraft should be investigated. Concurrent with the development of the aircraft modifications required to alleviate vortex effects at the source, the FAA should determine the aircraft certification and operational procedure changes needed.

48. That the FAA take the lead in establishing a national standard noise metric for aviation planning. This would ensure maximum compatibility with noise impact studies conducted in other environmental areas, and would allow for planning that accounts for the effects of population annoyance and ambient noise effects. This action should be followed by the establishment, in conjunction with user groups and other interested agencies and parties, of baseline acceptable noise level criteria for various types of aviation activities and land uses.

49. That planning criteria be developed that relate airport noise reduction, over a period of time, to additional airport capacity while at the same time reducing or stabilizing airport noise impacts on the community.

50. That the FAA should examine incentive for local jurisdictions to rezone adjacent noise impacted areas for compatible land use.

51. That FAA should vigorously resist any alteration of FAR Part 77.25, Civil Airport Imaginary Surfaces, that would effectively raise any of the surfaces as they exist today.

APPENDIX A

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NEW ENGINEERING & DEVELOPMENT INITIATIVES --
POLICY AND TECHNOLOGY CHOICES

CHAPTER III

FREEDOM OF AIRSPACE
Topic Group 3

Final Report

PART I

1.1 Introduction

During the months of work by Topic Group 3, an effort was made to deal with the broadest definition of all constraints to freedom of access. As a result, the definition of and possible means to relieve ATC airspace management constraints is only one of several significant areas in which the Topic Group invested its efforts. One result of this broad gauge approach to the topic is that some of the conclusions and recommendations are for initiatives other than Engineering and Development.

1.1.1 Methodology

In the initial stages of its work, Topic Group 3 undertook to identify, define and organize all constraints to the freedom of any user of the airspace to access any airspace of his choosing under any conditions of time, weather conditions, point of origin, route or destination. It was quickly apparent that different constraints were of significant importance to different types of users. It was also apparent that these different types of users constituted a constraint to each other. So in these initial stages and throughout its work the Group tried to avoid ranking either the constraints or the means to relieve constraints with any degree of priority or importance.

1.1.2 Organization of Task

After the Topic Group, as a whole, had identified the constraints it found desirable to consider and include in its report, a drafting format was adopted and drafting groups, each chaired by a member of the Topic Group, were established.

Constraint categories and the drafting group chairmen were chosen by the Group as follows:

1. Obstructions: John Winant
2. Weather: Victor Kayne
3. Airspace - Special Use: Robert Smith
4. Airspace - ATC or Alternative Management: Gilbert Quinby
5. Navigation Aids - Adequacy of Coverage and Accuracy: Edward Krupinski
6. Surveillance - Adequacy of Coverage and Quality: Paul Drouilhet
7. Communications - Adequacy of Coverage, Speed and Reliability: Roy Berube
8. Airports - Availability and Adequacy - Victor Kayne

1.1.3 Organization of Report

Part I of this report was drafted in its entirety by the Chairman and reviewed and approved by the Topic Group, following the completion of the work of the drafting groups on their sections. Part II of this chapter is composed of those final products of the drafting groups which were approved by the whole Group. Supplementary documents, where appropriate, are included as appendices.

Part I summarizes all constraint categories addressed by the Topic Group in Section 1.2, while Section 1.3 summarizes all of the recommended actions to relieve or reduce constraints. In Part II each section deals, to the extent possible, with individual the constraints and their relief.

1.2 Constraints: A Summary

While the following list is comprehensive, it does not pretend to be exhaustive. Readers may readily identify constraints which do not come under our heading categories of definition. Some of these were considered and deliberately rejected for reporting purposes because the constraint did not respond to the kind of E&D initiatives under consideration, or because the constraint was under more effective consideration by another Topic Group.

1.2.1 Obstructions

An initial and fundamental characteristic of the airspace under consideration is that it be navigable. To be navigable, it must be unobstructed. Yet study shows that the obstruction clearance plane is not a simple characteristic, and in fact constitutes a variable phenomenon subject to competition from a variety of non-aviation uses of airspace.

Minimum en route instrument flight altitudes are usually established by altitude margins for terrain clearance. In the terminal area, the design of approach, departure, missed approach, and holding airspace becomes increasingly influenced by cultural details supplementing the terrain clearance criteria. And while the terrain is reasonably stable and predictable in its altitude above datum, the cultural details with which the terrain is decorated are not. Vegetation grows. Structures are erected. And the airspace user is faced with an essential need to maintain and continually update obstruction clearance altitude and route information. The need to avoid obstructions, constitutes a capacity constraint, particularly in the design of terminal area airspace utilization.

1.2.2 Weather

The safe and efficient management of all phases of any flight, depends on the availability of accurate, timely, detailed weather information at the place and time needed by the airspace user. Any degradation of accuracy or detail, and any delay in time between the sensing and the utilization of weather information degrades the safety of the flight operation or constrains efficient use of airspace, or both. Weather is observed at only about 800 out of over 13,000 landing areas in the United States. Obviously not all these landing areas justify weather observation, since observations at one airport in a meteorologically stable region will suffice for operations at other surrounding airports. By the same token, weather service at an airport with relatively low usage and few based aircraft is neither justified nor expected. But for weather to be observed at less than half of the 1,700 airports in the U.S. having published Instrument Approach Procedures is an obvious deficiency. Weather information available to pilots is frequently more than one hour old as a result of frequency of observation, processing time and limited transmission circuit capacity. The timeliness of observations on severe weather phenomena are of particular importance because many of these phenomena associated with thunderstorms are short-lived. And the persistent inability to collect and disseminate in-flight weather information is a handicap, both to the planning and execution of flights and to the improved forecasting of aviation and other weather.

1.2.3 Airspace-Special Use

Some use of airspace is of such a special and unique character, that it justifies the exclusion of all other uses of that airspace for the duration of its special use. Such uses are typically (but not exclusively) military in nature and provide the most obvious example of one user constituting the constraint perceived by another user. It is clear that the maintenance of air crew proficiency in the application of exceptionally high performance aircraft to the sophisticated performance of advanced air warfare tactics is essential, and all possible means to exclude nonparticipating aircraft should be employed. On the other hand, all airspace users must be assured that such dedicated airspace for special use will be kept to a minimum and that nonparticipating traffic will be excluded only when the airspace is actually being employed for the mission justifying its dedication. If a lack of management, organization or facilities excludes aircraft from airspace not in use to serve its special mission, then capacity is needlessly wasted.

1.2.4 Airspace-ATC and Supplementary or Alternate Management

The members of Topic Group 3 studying freedom of airspace shared several areas of concern related to the present and projected system of air traffic control. There is, of course, a genuine concern for the statistically increasing risk of mid-air collision as more aircraft attempt to use the same popular airspace volume under essentially all weather conditions. Of perhaps unique importance to Topic

Group 3 is the converse concern that ATC constraints on freedom of access to airspace not be applied unless necessary and justified. And, within these bounding dimensions, there was agreement within the Group that an effort to continue to manage premium airspace in the face of steadily increasing demand by using the same procedures and control techniques and facilities as are in use today, will certainly constrain capacity because no conscious compromise of safety can be countenanced.

The most visible growth component of airspace users is the general aviation fleet, which presently numbers nearly 190,000 active aircraft. Unless constrained by natural or artificial means, this number is projected to double before the end of the century. While it is presently forecast to grow at an annual average rate of 4.3%, it is critical to note, for the purposes of this report, that the growth in IFR activity is forecast to exceed the rate of growth in fleet size and hours flown.

In the last few years, the helicopter fleet has been growing at an annual rate in excess of 12%, nearly three times the rate of growth of the total general aviation fleet. Industry forecasts estimate a helicopter fleet of over 10,000 by the mid-1980s, with about 5,000 of this number capable of IFR operations in instrument meteorological conditions.

By any acceptable forecasting process, it seems reasonable to predict a doubling of present demand by the end of decade of the '90s. It is doubtful that the projected growth in demand can be accommodated in the procedures, techniques and facilities presently applied by ATC to manage the safe and efficient flow of air traffic. So it is necessary either to modify the "constrained" forecast of growth to add the constraint of limiting capacity at acceptable safety standards, or to seek new alternate or supplementary aids to the existing system of air traffic management so that its capacity can grow at a rate equal to, or in excess of, the anticipated rate of growth in demand, while providing safety equal to, or better than, that which exists today.

Early in the deliberations of the full Group it was acknowledged that the capacity of a given volume of airspace was greater in visual meteorological conditions, with aircraft separated in accordance with Visual Flight Rules (VFR), than it was in Instrument Meteorological Conditions (IMC), when aircraft are separated by Instrument Flight Rules (IFR). The amount of difference in capacity varied, depending upon other conditions, but it appeared to the Group that with the exception of the top 25 very high density terminal airspaces, there would be no capacity limitation today, or in the forecast future, if aircraft could be safely separated in instrument meteorological conditions using the criteria applied under VFR. This concept was variously called electronic VFR, elecronic see-and-avoid, or electronic flight rules, at various stages in the Group's discussions.

1.2.5 Navigation Deficiencies

The International Standard Short-Range Air Navigation System, VOR in the VHF frequency spectrum and DME in the 1,000 MHz region, has a number of limitations. For one thing, it is effective only over radio line of sight, which leaves a lot of low altitude airspace outside of coverage. This also calls for the establishment of a relatively large number of transmitting sites which provide the potential for co-channel frequency interference at high altitudes. The navigation signal format is in polar coordinates and there is a reduction of accuracy as distance from the transmitting site increases. Both, coverage deficiency and accuracy reduction, offer their own separate constraints to full airspace utilization.

Particularly offended in this regard is the increasing fleet segment of Instrument Flight Rules (IFR) qualified rotary-wing aircraft. The mission of the helicopter frequently involves flight beyond, or below, line of sight range from a navigation facility. And with an increasing share of the rotary-wing fleet equipped and qualified to operate in instrument meteorological conditions, this lack of coverage and accuracy has driven operators to seek alternative navigation solutions.

Appendix C of this chapter, provides a review of the limitations and advantages of existing and alternate navigation techniques under consideration. It is important to remember that navigation coverage and accuracy is one of the common denominators involved in all of the foregoing listed constraints from obstruction clearance to Air Traffic Control (ATC) system efficacy.

1.2.5.1 Vertical Separation Above Flight Level 290

A special case of navigation accuracy deficiencies imposing a constraint on freedom of access of IFR airspace is the need for increased vertical separation of traffic above 29,000 feet altitude (FL/290). Errors in the altitude measuring systems of aircraft used at these altitudes lead to wider tolerances in vertical navigation, and a vertical separation of 2,000 feet, rather than 1,000 feet used as standard below FL/290. Thus, the en route capacity of the most fuel efficient altitudes for turbojet aircraft is only half that of lower altitudes.

1.2.6 Surveillance Deficiencies

A proposal addressed by Topic Groups 1 and 4 received extensive discussion in Topic Group 3. This proposal was to permit surveillance in the en route airspace to transition from the present format of secondary surveillance radar supplemented by the primarv radar into a format increasingly served by secondary surveillance radar only. Most technical, operational and safety aspects of this issue are dealt

with most adequately by the other Topic Groups. But a freedom of airspace issue is also involved and a concern in Topic Group 3 must be expressed here. Some unknown, but very small fraction of the total aircraft handled by ATC under IFR either have no transponder installed, or have a malfunctioning transponder which requires the backup use of primary radar in the en route environment. Efforts to quantify this fraction were unsuccessful, but it is surely less than 10% of the traffic and possibly as little as 1% of the IFR hours exposed. Nevertheless, Topic Group 3 must express a concern over the possibility that the regulatory constraint of mandatory carriage of transponder for all en route IFR operations would be a consequence of the phase-out of primary radar. Even more serious is the lack of altitude encoders in the fleet, which recommends caution in regulating mandatory carriage of Mode C.

1.2.7 Communication Deficiencies

Communication deficiencies are common to many limitations on freedom of access to airspace. And VHF communications, like VHF navigation, has its line of sight problems in low altitude coverage and high altitude interference. But the speed and accuracy and reliability of communications within interference-free coverage is tremendously dependent on a number of human factors. It is the documented prevalence of persistent human errors in voice communication that justifies our concern. Section 2.7 in Part II and Appendix E, of this chapter, offer documentation of the delays and hazards, which result from poor communication procedures and practices. One is led to the conclusion that an aviation system, which depends on voice communications to link the highly automated ground ATC facility with equally sophisticated aircraft capability, is badly overdue for a fundamental review of system architecture.

Airspace users participating in the deliberations of Topic Group 3 were, of course, generally aware of the advent of improved communications capability through such programs as the Discrete Address Beacon System (DABS) and reduction of communications requirements through extensive use of Area Navigation (RNAV). But it is characteristic of the caution of these users of airspace, as well as the ATC control element, that heavy emphasis was placed on the correction of deficiencies in the voice communication system, while exploring the potential, application and implementation process of the new digital system. It would be a serious operating constraint and safety error to neglect opportunities to improve the voice communication system because we are getting ready to begin an evolutionary transition to more digital communication. Because of this concern, the committee's emphasis is on the application of procedural, regulatory and technical corrections for the identified deficiencies of the voice communication system, which the Group is confident will be with us in one form or another for a very long time, even after the DABS and other sophisticated digital communication processes are securely in place.

1.2.8 Airport Deficiencies

General aviation is frequently inhibited in its effort to fulfill its missions by the lack of an airport within reasonable distance of a desired destination, or by the inadequacy of the airport most convenient to a destination. Topic Group 3 identifies these deficiencies as constraints to the full efficient use of the airspace and endorses the comments in this regard presented in Section 2.8 of Part II of this chapter.

1.2.9 Helicopter IFR - Unique Requirements

It is only in recent years that the rotary-wing segment of our airspace user community has become a regular user of the ATC system in Instrument Meteorological Conditions. Today, and increasingly in the future, a substantial segment of the rotary-wing fleet is fully qualified for IFR operations. But there are obvious incompatibilities between the flight characteristics and mission profile of the rotary-wing aircraft, and the capacity and procedures of an IFR system designed for fixed-wing aircraft. It is because of this incompatibility and because of the increasing frequency and importance of helicopter IFR operations, that a separate section in Part II, of this chapter, is devoted to the subject.

Helicopter operation is severly constrained by the lack of low altitude navigation, surveillance and communications coverage. As a result, vital missions with rotary-wing aircraft, outside the coverage of any element of the ATC system in Instrument Meteorological Conditions (IMC), are being conducted with less than optimum safety and reliability, or are not being conducted at all, thus failing to fulfill missions of which the helicopter is otherwise uniquely capable.

1.3 Means to Relieve or Reduce Constraints: A Summary

In this section various means proposed by the Group to relieve the constraints to free access to airspace will be identified. The Group frequently identified constraint reliefs of a procedural, publication, regulatory, or even legislative nature, which deserved documentation.

No means to relieve a constraint to freedom of access of airspace can be tolerated if it results in a degradation of safety. A constraint relief must, as a minimum, maintain the high safety standards characteristic of the National Aviation System (NAS), or, if possible, improve on them.

1.3.1 Obstructions

In airspace where critical flight patterns are particularly inhibited by obstructions, a review of clearance criteria is probably justified. If procedures can

be authorized at reduced obstruction clearance limits, provided certain navigation accuracies are met, the constraint of the obstruction could be relieved for those airspace users who are able to demonstrate suitable performance, or who find the relief of the constraint worth the "price" of performance improvement.

Review the regulatory responsibility for the control of man-made obstacles. Establish a fair balance between the use of airspace for the transit of aircraft and the use of airspace for other purposes. For example, industry association advocates from aviation and broadcasting might be called upon to propose mutually satisfactory guidelines for tall tower construction with respect to navigable airspace.

In addition to the technical opportunities of further refining navigation and altimeter accuracies, explore means for improved visual or electronic marking of prominent obstructions. Guy wires, for example, are inadequately marked and never lighted.

1.3.2 Weather

Accelerate the present activities which will lead to automation of aviation weather observation and dissemination. Work towards a goal of instant availability of real-time weather at airports with instrument approach procedures via radio link to aircraft in flight and telephone link for flight planning.

Continue present work towards the improvement of short-term forecasts, taking full advantage of the anticipated availability of an increased weather data base from automatic observation points.

Develop a systematic means to sense or observe in-flight weather and incorporate the in-flight observations in the forecasting process, as well as distributing it for flight planning and execution.

Improve the timeliness and forecasting of severe weather phenomena, such as thunderstorms, gust fronts and wind shear.

Continue to improve weather data distribution, including the provision of direct accessibility to automatic weather sensors by telephone and radio to supplement higher capacity teletype circuits, modernization and automation of Flight Service Station functions, and any other appropriate improvements in information transfer.

Finally, there should be a formal review of and recommended improvements to the bifurcated federal bureaucracy responsible for weather research and development, weather sensing, weather information distribution, and perhaps, even

weather modification. It is possible that this would constitute a legislative initiative.

1.3.3 Special Use Airspace

While the provisions for managing special use airspace appear to be adequately set forth in FAA and other agencies' manuals of procedure, the actual execution of that management, in accordance with those provisions, leaves much to be desired. There is room for considerable improvement in communications, centralizing and identification of responsibility, and backup contingency procedures, so as to optimize joint use of the special use areas.

Topic Group 3 found that existing procedures by which FAA and the Department of Defense periodically review the need for, dimensions of and management of special use airspace are satisfactory and effective. Because of this successful interaction between FAA and DOD in planning the optimum joint use of special use airspace, it should be possible to quickly and effectively make the improvements in management noted above.

With the exception of some improvement in communication coverage and status applicable to the management of special use airspace, there appeared to be no worthwhile technical E&D approaches justifying serious consideration.

1.3.4 Airspace - ATC and Supplementary or Alternative Management

In its examination of alternatives to today's air traffic control procedures that could reduce the constraints that these procedures cause, the Group evolved a concept called Electronic Flight Rules (EFR). This concept would allow suitably equipped aircraft to use today's VFR operating procedures in certain airspace under IMC, for example, aircraft would be able to operate in this airspace in IMC without the constraints of an IFR flight plan and ATC clearance.

The Group recognized that EFR is fundamentally different from collision avoidance (CAS). The latter refers to backup techniques or systems which attempt to provide for safe aircraft passage in the event of a failure in the primary mode of traffic separation (ATC). EFR, on the other hand, assumes primary responsibility for separating aircraft, and, in cooperation with ATC, from aircraft operating under IFR clearances.

The Group recognized certain limitations of EFR, including initial applicability in lower density airspace, and the need to interact with conventional ATC. However, the Group believes the EFR concept shows sufficient promise for alleviating ATC-induced constraints and it recommends the FAA pursue an aggressive E&D program to examine and fully evaluate alternative means of realizing this concept.

1.3.5 Navigation

After consideration of a number of alternative plans to relieve the coverage and accuracy constraints of the present navigation system, the Group concluded that hasty replacement of the international standard short-range navigation system of VOR and DME would be a serious strategic error, as its replacement system is not now evident, either as to type or timing. There are obvious advantages to a satellite based system if cost-effective, but this is yet to be demonstrated. While the appropriate scientific and operational evaluation of optimum satellite based technology forecasting, scheduling and implementation proceed, it will continue to be vitally important to pursue E&D initiatives to take fullest possible advantage of the capability of the existing International Standard System of VOR/DME.

Technical and operational planning initiatives should be undertaken in the efficient utilization of flight levels above 29,000 feet. Altimeter accuracies necessary to provide equal, or better, safety with vertical separations of less 2,000 feet should be established. Capability of existing air data systems to provide the needed accuracies should be assessed. If this program does not provide for a reduction of the 2,000 foot altitude separation then further E&D initiatives will have been defined towards that objective and should be pursued.

1.3.6 Surveillance

If primary radar is permitted to be phased out in the en route airspace its backup role in aircraft tracking and separation will have to be replaced with suitable procedures. Today, there are procedures for the continuation or successful termination of an IFR flight operation in the event of communication failure. An equally effective similar set of procedures should be developed for transponder failure in instrument conditions in airspace surveilled only by secondary surveillance radar.

1.3.7 Communication

Most of the constraining aspects of voice communication in the National Aviation System will respond only to a multiplicity of small procedural and publication reliefs. Eventual complete relief of the coverage constraint will await the economic feasibility and development of satellite based communications with the strategic planning and scheduling cautions similar to those applied above to the development of satellite based navigation. Improvements in speed, accuracy and reliability of communications, from whatever terrestrial or extraterrestrial source, will be small until we begin the conversion process to digital communication techniques. The advent of DABS data link capacity gives us our first significant opportunity to define the optimum format and functions which lend themselves to digital communication. Studies should be conducted to establish the importance of

"party-line" peripheral communications and the impact on safety and capacity if digital "private-line" communications are substituted. Optimum mix between broadcast information and discreetly addressed or accessed information, particularly in the dissemination of weather data, should be assessed. More use should be made of published procedures, such as conventional and RNAV SIDS and STAR, rather than ad hoc, or radar vector navigation by controllers. It should be possible to use both systems to their optimum advantage, but not be rigidly cast in the use of published procedures where radar vectors make more efficient use of airspace or vice versa.

1.3.8 Airport

Tax relief or other incentives should be investigated to supplement federal, state and municipal subsidy to establish and maintain airports. Particular attention should be given to the metropolitan areas of high population density so that the growing trend of reducing airport inventory can be reversed.

1.3.9 Helicopter IFR Operating Requirements

Rotary-wing operators need improved coverage and effectiveness of navigation, surveillance and communication services if they are to fulfill the potential of the helicopter in instrument meteorological conditions. Safety aspects of navigation, surveillance and communication services evolved for the management of fixed wing IFR traffic cannot be compromised in an effort to better serve the IFR helicopter mission. And the cost of facilitating vastly increased coverage of the present services are prohibitive. So the Group concluded that for the short- and medium-term future, the helicopter operator would continue to benefit from the use of solutions unique to the helicopter mission, such as VLF, airborne radar approaches and discrete route structures now emerging.

1.4 Topic Group Work Statement

This section provides answers to some of the questions asked in the work statement provided to Topic Group 3.

1.4.1 Questions to Which Answers Are Desired, and Constraint Reliefs Applicable to Work Statement Questions

1. How can the FAA develop a system that permits the maximum freedom of airspace use to both large and small aircraft of various capabilities at the lowest possible financial and environmental cost and the highest practical level of safety?

Establish the technical feasibility and cost-effectiveness of operation by Electronic Flight Rules (EFR). Provide operating benefits, such as simplified or expedited clearances when users install the system as a supplement to conventional ATC services. Plan the evolution of air traffic management to eventually unload traffic separation responsibility in certain airspace from the conventional ATC system to an automated traffic separation system, when proven. (See Sections 1.2.4 and 1.3.4 above and Section 2.4 of Part II.)

2. Does increased automation, which may require improved surveillance and more extensive use of transponders, permit a more flexible route structure and greater freedom in the use of the airspace?

Increased automation including increased use of ATC radar beacon transponders and discrete address beacon transponders can be implemented so as to permit a more flexible route structure and greater freedom. Users will install transponders and other devices if the installation will benefit their operations. Increased automation and extensive transponder implementation can be used to provide more convenient direct routings with improved separation assurance as a result of ground processed traffic avoidance, and resolution service which would be perceived as a benefit by users. (See Sections 2.4 and 2.7.)

3. Would mandatory equippage of Mode C transponder (ATCRBS transitioning to DABS with data link) on aircraft, in addition to providing productivity and safety benefits, serve to provide greater flexibility for uncontrolled aircraft desiring to fly in, or near, high density airspace?

No. Present procedures exclude many aircraft desiring transit, even when equipped.

4. Can the data link capability of DABS permit a better level of controlled VFR service in TCAs?

Yes, by virtue of improved communications and timely weather information.

5. Are there other data link services that could and should be provided?

Data link services are essential to EFR, ATARS and CDTI, and weather information as described in Section 1.3.2 above. Electronic Flight Rules (EFR) conceptually developed in Section 2.4 requires an air-to-air data link. Automatic Traffic Advisory and Resolution Service (ATARS) is the ground-computed version of the EFR concept and needs ground-air data transfer.

Other noteworthy candidate systems include Automated En Route ATC (AERA) and Cockpit Display of Traffic Information (CDTI), both of which would make extensive use of data link.

So the common denominator to most of the traffic separation systems proposed is the capability to transfer data quickly and accurately. Data to be transferred for this purpose might include:

a. Frequency changes indicated or executed.
b. Position of relevant traffic.
c. Position of relevant obstructions (MSAW).
d. Clearances including time speed command.
e. Vectors.
f. Ground-computed avoidance maneuvers (up-linked).
g. Air-computed avoidance maneuvers (down-linked).
h. ATIS.

6. Are there ways of structuring and monitoring the airspace to permit freedom of operation without requiring ATCRBS or DABS transponders while still ensuring safety in mixed and positively controlled airspace?

No. Use of the terms structuring and monitoring and ensuring safety in mixed and positive controlled airspace strongly implies that the airspace in question is controlled airspace. Topic Group 3 was unable to conceive any practical supplementary or alternative system of airspace management which did not require cooperating devices on all participating aircraft.

There was a consensus expressed in the Group that uncontrolled airspace outside of terminal control areas and below some nominal altitude of 5,000 or 10,000 feet should be protected for the use of unequipped aircraft engaged in training, recreational flying, special industrial or agricultural operations, soaring, ballooning and similar activities. Study is recommended to assure that such airspace exists and offers VFR utility to unequipped users without infringing upon the air transportation activities taking place in controlled, mixed and positive controlled airspace above and around it. Unequipped, low altitude, cross-country transportation should be practical, if not always convenient, in this airspace.

7. Will shifts or increases in aircraft noise impacts, due to technological or other system changes, create limitations on the actual use of those changes?

This question was not addressed by Topic Group 3.

8. FAA has a number of efforts underway that relate to inefficient routes. For example, a restructuring of en route airspace might permit the use of more efficient altitudes on the New York to Washington routes. However, this would increase the workload of certain sector controllers due to crossing traffic flows. The AERA program has as one of its objectives, a reduction in controller workload and might make such a restructuring feasible, thereby providing optimum altitude routes between city pairs. RNAV, based on current navigation system can also provide direct routings and simplified navigation in terminal airspace. INS is now used for direct routings on long distance flights. What are the technological and institutional barriers to greater use of efficient routings and what are the benefits from such routings, and what programs should the FAA undertake to overcome these barriers?

This question is addressed in Sections 2.2.4, 2.2.5, and 2.2.7. It also has elements of special use airspace management addressed in Section 2.2.3. We believe a significant number of the recommended E&D initiatives listed below are responsive to this broad question.

9. According to NTSB reports, weather is a contributing factor or cause in about 40% of all fatal accidents. Typical among the factors are low ceiling, fog, rain, and continued VFR flight into adverse weather.

FAA has a number of programs for improving weather services. FSS modernization includes several improvements to mass weather dissemination and weather briefings. Further, FAA has under development an Automated Low Cost Weather Observation System (ALWOS) for use at general aviation airports with approved instrument approaches which currently do not have local observations. In addition, FAA has under development a semi-automated weather observation system for use at Air Traffic Control Towers designated to take weather observations.

Are there additional programs that FAA should undertake? What should be the next steps in the development and provision of improved weather services? Should warnings of severe weather be gathered automatically from aircraft and relayed to concerned aircraft via the DABS data link?

Section 2.2 of Part II, of this chapter, as well as Sections 1.2.2 and 1.3.2, above, respond to this question.

1.5 Recommendations for E&D Initiatives

Although not limited to E&D the following FAA initiatives are recommended by Topic Group 3:

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NEW ENGINEERING & DEVELOPMENT INITIATIVES -- POLICY AND TECHNOL--ETC(U)
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Obstructions:

- Develop technology and methods to reduce obstruction clearance criteria without degrading safety.

- Explore means for better visual and electronic marking of prominent obstructions.

- Use FAA agreements and trust fund resources to better control obstructions.

Weather:

- Develop automated weather sampling methods to reduce processing time and manpower. Reduce weather transmission circuit delay and increase circuit capacity.

- Develop methods and formats to prioritize weather information on the basis of its criticality.

- Develop technology to improve weather data distribution, toward the objective of providing real-time weather to users, both for pre-flight and inflight planning.

- Develop a method of collecting and dissemination en route weather information, preferably automatically sensed and transmitted via a data link.

- Continue testing and expand development of reliable wind shear detection techniques and compensation methods and procedures.

- Expedite automation of aviation weather observations.

- Develop a method to improve short-term weather forecasts, with particular emphasis on severe phenomena, such as gust fronts, wind shears, and thunderstorms.

- Weather sensing radar to replace primary ATC radar.

Special Use Airspace:

- Improve communications, identification of responsibility and centralization and contingency procedures to optimize joint use of special use airspace. Make appropriate and timely information available at all centers.

Air Traffic Control:

- Supplement the M&S development program to include RNAV and other cockpit navigation and time/speed referenced commands to augment the current radar vector commands in terminal areas.

- Develop and test ATC supplementary control concepts, such as EFR. Evaluate extension of EFR to ATCRBS airspace and to airspace not currently under surveillance.

Navigation:

- Explore means to reduce existing separation criteria by use of more accurate navigation equipment using existing navigation systems.

- Analyze and determine the optimum mix between preplanned published navigation procedures and ad hoc radar vector navigation techniques. Establish the best techniques for use in various environments of traffic density, traffic mix and weather.

- Continue long-range E&D of satellite-based navigation.

- FAA RNAV policy statement was adopted over two years ago but is still not implemented. Implement it. Undertake an analysis to determine why RNAV is still underutilized in the ATC system. Establish action programs to correct identified deficiencies.

- Direct routes that are regularly used by RNAV equipped aircraft should be designated for ease in flight plan filing and handling by both ATC and users. A master high altitude en route RNAV airway plan should be developed so that implementation of portions where there is a user requirement may be accomplished in a systematic fashion.

- Test, sample and quantatively determine the current 2-sigma and 3-sigma deviations in altimetry error existing above FL 290 for aircraft with and without air data computers.

- Develop, test and publish methods and techniques and MOPS which would permit 1,000 feet vertical separation above FL 290.

- Designate airspace (routes) where equipment meeting MOPS standards would be authorized 1,000 feet vertical separation above FL 290.

Surveillance Radar:

- E&D should be oriented toward developing the role of primary radar toward the detection and mapping of hazardous weather rather than aircraft tracking.

Communications:

- Develop, test and implement methods and techniques to reduce mutual interfering VHF communications.

- Define and accurately identify existing VHF communications coverage deficiencies.

- Integrate and publish a national aviation communications plan, including funding, equipment, manpower and timetable to upgrade the entire aviation voice and data communications network, air-to-ground and point-to-point.

- Modify communications procedures to reduce congestion and enhance safety, including simplified flight plan filing.

- Test, evaluate and determine the optimum mix between "party line" broadcast information and discretely addressed information.

- Implement increased use of cockpit navigation by published procedures to reduce dependence on radar vectors and communications.

Helicopter:

- Select and test technology and procedures to improve the communication, navigation and surveillance coverage for helicopter low altitude IFR operations.

Airports:

- Develop a national program for retention and review program of GA airports with special attention to those needed to relieve traffic at congested major hub airports.

PART II

2.1 Obstructions

2.1.1. Definition:

An obstruction to air navigation is any object which intrudes into the airspace sufficiently to cause an increase in the minimum altitudes at which aircraft otherwise could fly or which interferes with the operation of any air navigation facility, or interferes with the view from an airport traffic control tower of aircraft movement areas, either on or off the airport.

2.1.2 Explanation and Examples:

Such objects may be physical and natural, such as mountainous terrain. They may be objects constructed by man, such as a tall building or communications transmitting tower. They may have no physical consideration for flight, but may block or reflect electromagnetic radiation in the vicinity of navigational aids, like radio or radar installations.

Obstructions exist in and have effects peculiar to the three regimes of flight: those in the departure area, the en route environment, and the terminal area.

With respect to the departure area, obstructions in the airport vicinity have a limiting effect on runway placement, effective length and runway use. They also have an effect on departure and missed approach flight procedures.

The impact of departure area obstructions is to impose constraints on the flow of traffic outbound from the airport. Under VFR, obstructions may require climb on specific courses which cause increased spacing of successive departing aircraft. Under IFR conditions, all meteorological (ceiling and visibility) restrictions and specific climb requirements are placed on the flow of departure traffic as a direct result of obstructions. Delays in traffic are the direct result of such constraints, as well as reduced aircraft load carrying capabilities.

In the en route phase of flight, terrain intrusion into otherwise usable airspace constitutes the principal obstruction. This kind of obstruction can have two types of constraint on flight: to raise the minimum altitude at which flight may be conducted, or to divert traffic to one side or the other of the terrain obstruction. The constraints caused by en route obstructions are felt particularly keenly, in terms of diversions from a "straight" or "level" routing path, at that point in flight where the transition from en route to approach phase begins, as well

as in the case of high minimum altitudes where there is a loss of highly valuable airspace for maneuvering to land. En route obstructions also have an indirect and constraining effect in that they cause airspace to be inefficiently organized.

Terminal area obstructions have effects similar in nature to those which constrain departure techniques. Traffic must be spaced and made subject to finite procedural paths to circumnavigate the obstructions, with resulting delay in completion of flight. The most significant constraints are caused by obstructions located in the final approach area which require displaced and/or relocated thresholds and result in excessively high Decision Heights and Minimum Descent Altitudes. These constraints as a direct result of obstructions severely affect airport capacity and utility.

2.1.3 Means to Reduce, Relieve or Remove Constraints

2.1.3.1 Procedural

Develop technology and methods to reduce obstruction clearance criteria. In the IFR en route environment investigate reduction of the required vertical clearance and reduction of the present route width within safety limitations. In the IFR terminal environment, review TERPS procedures and other means of reducing the required vertical clearance for nonprecision approaches and place top priority on the establishment of precision instrument approach systems. Develop an instrument departure procedure system that is capable of providing both lateral and vertical guidance. Investigate vertical clearance requirements for "semi-precision approaches", i.e., approaches made with the assistance of automatically calculated and continously displayed vertical path information, to determine if these clearances may be reduced.

2.1.3.2 Regulatory

Require strict adherence to existing Federal Aid to Airport agreements concerning control of obstructions at obligated airports. Exercise "positive control" over the intrusion of obstructions through zoning laws and other means of local and/or state control which will protect the navigable airspace around airports. Inhibit the creation of manmade obstructions by limiting the height of such structures in navigable airspace; exercise more control over manmade obstructions by statute, through which regulation may be effectively achieved. Encourage the Federal government to more rigorously consider the efficiency and safety of aircraft movement with respect to FAA's total involvement in determinations of hazard, with respect to all man-made obstructions. Last, improve and expand reimburseable obstruction removal programs under the Airport and Airway Development Act.

2.1.3.3 Technical/Innovative

Review all existing procedures applicable to the impact of obstructions on aerial navigation. Included in such review should be means by which to safely reduce existing separation criteria by use of more accurate navigation equipment and techniques, e.g., RNAV equipment, ILS and MLS. Exploration should be made to improve visual and electronic marking techniques for pilot location of obstructions. Make more effective use of altitude information in Standard Instrument Approach and Departure Procedures and Profile Descents.

2.2 Weather

This section outlines several problem areas with regard to Aviation Weather. It does not treat the respective areas of responsibility of the National Weather Service or the Federal Aviation Administration in this field since these responsibilities are assigned by the Congress and currently are under review by appropriate committees of the body. It is noteworthy that one User Group - AOPA - has recommended to the Congress that the responsibility for all weather requirements, including specialized services for aviation and other uses, be assigned to one agency that would be responsible for observation, forecasting, collection, distribution and R&D.

2.2.1 Weather as a Constraint

The lack of adequate or accurate weather information can be a constraint to the freedom of use or the efficient utilization of the airspace. It also is a primary safety consideration.

The requirements for aviation weather information stem from needs for preflight planning, in-flight operations, forecasting activities of the responsible agency and the overall contribution that aeronautical meteorological information makes to the provision of weather information for general public consumption.

2.2.2 Explanation and Examples

2.2.2.1 Observations

Weather has been cited by NTSB as a cause or factor in four of every ten fatal accidents and two of every ten non-fatal accidents in general aviation for a number of years. The general aviation accident rate could be improved substantially if accurate and timely weather information could be obtained readily by general aviation pilots. However, little recognition has been given to the fact that the lack of surface weather observations at many airports has an inhibiting effect, on operations, both from the viewpoint of efficient utilization of the airspace and from a safety standpoint.

There are almost 1,000 airports that have published instrument approaches that do not have on-site weather observing capability. Further, there are thousands of airports used for VFR operations that do not have even a simple wind direction and velocity readout available to those using the landing surface. In precipitous terrain, the instrument approach procedures are derogated during those hours when an altimeter setting is not available from the airport.

Despite significant progress in satellite observation techniques, extensive computer and communications capabilities, and large efforts in research and development, there has been little progress in providing weather observations at the growing number of airports that have either, or both, a published instrument approach procedure or a large number of based aircraft.

A study made in 1976 by Mr. Samuel V. Wyatt for AOPA listed all airports with approved instrument approach procedures together with the weather observation services, if any, and the number of recorded IFR approaches made by general aviation aircraft. This study revealed that of the 1,707 airports with approved instrument procedures, 914 had no weather observation service.

It is neither economically feasible nor desirable to station U.S. government personnel (either FAA or NWS) at all airports where weather observations are required. Further, it is recognized that training and certification of observers supplied by nongovernment organizations would impose a burden on the National Weather Service. It is unattractive to airport management and fixed base operators due to costs involved for the purchase of approved observing equipment and supplying trained observers, even though weather observations are collateral duties. Nevertheless, this system must be used until automatic observing systems becomes practical.

2.2.2.2 Forecasting

Forecasting of expected weather conditions is essential to safe and efficient utilization of the airspace. If pilots encounter unexpected severe weather, safety can be derogated. On the other hand, if inaccruate forecasts predict adverse or unflyable weather that, in fact, does not exist or materialize, then pilots can be in the position of canceling or diverting flight when the flight could have been accomplished without undue difficulty.

The use of computer techniques for forecasting weather, including winds aloft, has caused a considerable amount of dissatisfaction among the users due to the inaccuracies of those forecasts.

2.2.2.3 In-Flight Weather

The aviation community continues to suffer from lack of information regarding the actual or real-time weather aloft despite the existence of thousands of flights daily throughout the airspace. These flights could be an effective system of airborne sensors or observation platforms for reporting essential elements to those on the ground.

At the present time, a considerable number of pilot reports (PIREPS) are made to various ground personnel, including ATC, FSS and company radio systems. However, only a small fraction of those reports ever get into the ground distribution system or are forwarded to the meteorologists responsible for forecasting conditions aloft. What is even worse is that many reports are made regarding elements such as tops, icing levels, turbulence and thunderstorm activity that never reach other pilots who are about to enter the area involved. Probably the most effective use and dissemination of pilot reports is that accomplished through the EFAS (En Route Flight Advisory Service) now in operation through selected Flight Service Stations across the country.

2.2.2.4 Wind Shear

Wind shear in the final approach zone and along the takeoff path of an airport can be a serious constraint to the operation of large jet aircraft. The problems of wind shear have not been considered to be a serious constraint or safety threat to relatively lighter general aviation aircraft over the years due to the much lower mass and quick response capability of the average general aviation aircraft to application of power in time of need. However, with the heavier transport jets and the slower response time of jet power plants, wind shear has become a significant constraint and safety consideration for this type of aircraft.

There are many ground-based and airborne wind shear detection and compensation techniques being investigated, tested and used among which are:

1. Cockpit ground speed display and compensation of ground speed variation.
2. Laser, acoustic and radar beam sensing of wind velocity profiles.
3. Strategically located ground based anemometer arrays to anticipate gust fronts in critical airspace.
4. Accelerometer and INS direct sensing of wind variation.

Classic wind shear accidents have provided a data base adequate to accurately model the shears and various procedures and detection techniques can very reasonably be tested against the models. FAA E&D should continue efforts to develop and test additional reliable techniques, equipment and procedures to cope with this serious problem.

2.2.2.5 Accessibility and Dissemination

One of the major problems facing the users of aviation weather information is the limited accessibility to that information and the limitations of dissemination suffered under the present system operation.

Almost all preflight planning for general aviation depends on information obtained from the Flight Service Stations operated by the FAA. With more than 13,000 airports in the United States and approximately 300 Flight Service Stations, it is obvious that most of the pre-flight briefing must be accomplished by remote means, usually through telephone access. It also is obvious that the volume of the demand for briefing information cannot be accomplished on the basis of one-on-one, with one briefer for each pilot request.

In many areas another critical problem is that of passing time critical information to pilots regarding thunderstorm activity and other severe weather phenomena in areas that they are about to enter. This requires means to acquire the information, such as weather radar in FSS and air route traffic control centers, means to make that information available to all concerned ground personnel and the timely passing of the information to all aircraft concerned. Failure to do this constrains use of some airspace due to lack of information that it is clear of severe weather phenomena. It is, of course, a safety problem as well.

2.2.3 Means to Reduce or Relieve Weather Constraints

2.2.3.1 Automatic Observations

The Secretary of Commerce and the Secretary of Transportation were advised by nine aviation organizations under date of June 20, 1977 of recommendations for the provision of adequate surface observations through either automatic or manual means. The objective was to specify only those elements of weather that have a significant influence on safety and, where practicable, be susceptible to automatic observation with direct readout by uncertificated airport personnel, such as airport "UNICOM" operators. The following elements were recommended as miniumum requirements for observations at a single site on an airport:

a. Height of clouds at or below 5,000 feet
b. Visibility or visual range
c. Wind direction and velocity
d. Temperature
e. Altimeter setting

A sixth element, dew point, is considered mandatory by some users, but was left off the minimum required list only because sensing technology has not yet been

perfected. Automation of minimum requirements should not be delayed, but parallel research on automatic sensing of dew point should be completed as quickly as possible.

The following additional elements were considered desirable but not essential:

f. Precipitation
g. Peak gusts
h. Average, trend and prevailing cloud height
i. Obstructions to vision

The nine associations then recommended:

1. The FAA use its authority under the Airport and Airway Development Act to make grants to states and other eligible bodies for the purchase of approved manual or automatic weather observing equipment.

2. The NWS be staffed to cooperate fully with any purchaser of weather observing equipment in providing training and certification of observers as required.

3. That the FAA field test simple cloud-height and visibility measuring devices (such as automatic ceilometers and back-scatter devices) to determine their operational usefulness if the measurements are read by uncertificated personnel or the information is transmitted automatically to pilots or to a collection station.

4. To the extent the operational test proves feasible, the FAA use "cloud height" and "visibility" to define landing and takeoff weather requirements, if appropriate, to the type of operation involved.

In addition to the need for equipment for automatic surface observations, there exists a need for automatic means of making observations of surface wind and altimeter setting and to provide access to these through radio query initiated by the pilot.

The solution to these problems, through automatic devices, is subject to E&D initiatives.

2.2.3.2 Forecasting

Better techniques need to be developed for real time and short-range forecasts, possibly with satellite assistance, for items such as cloud cover and

winds aloft. Other critical items include thunderstorm activity, tops of cloud layers, icing levels and turbulence.

Further, the feasibility of including a short-term forecast at the end of each sequence report should be investigated. This might cover a three-hour period and include trends and percent of confidence.

These problems should be examined to determine if E&D initiatives could play a role in more effective forecasting.

2.2.3.3 In-Flight Weather

In-flight weather information is distributed by pilot reports to a number of ground points, including FSS, ATC controllers, company radio, UNICOM stations, flight school stations and flight test stations. Additionally, military pilots make reports to their own facilities. There is little cross-feeding of these reports to other facilities and often not to pilots in the air or to the responsible weather service facility.

The means to improve the distribution of in-flight weather information through better dissemination in the ground system should be the subject of both operational decisions and E&D initiatives. Techniques should be developed for collecting, analyzing, formating and disseminating en route weather information analogous to what is currently done for terminal weather. It is envisioned that the principal source of data would be aircraft operating in the airspace; this data would be either manually provided by the pilot or automatically sensed and transmitted via data link. The goal would be periodic en route reports, giving current en route conditions on a route and/or area basis, including winds and temperature aloft, cloud heights, including layer structures, icing conditions, turbulence, etc.

R&D effort is also required to develop sensors for use on aircraft that will automatically observe and encode in-flight weather information.

2.2.3.4 Wind Shear

Mitigation of the wind shear problem appears to depend on the detection and timely provision of wind shear information to the pilot. Some techniques being developed, including data provided from aircraft equipped to sense wind, appear promising.

2.2.3.5 Accessibility and Dissemination

A modernized FSS System is required for adequate accessibility and dissemination. It should include mass dissemination techniques, such as low-frequency and

VHF radio broadcasts, taped telephone access and computer-generated voice response systems.

The aviation community has been working with the FAA for many years in an effort to improve the FSS system, but the program is lagging badly. This is one area where the E&D efforts have been extensive and solutions have been developed so as to permit a more efficient and usable system. The present problem appears to be more of a lack of expedient operational decisions rather than the need for more E&D. In fact, additional E&D might have the effect of unduly delaying installation of a modernized system.

Valuable teletype circuit time frequently is occupied by NOTAM's that appear to be low priority messages. Circuit priorities should be examined to determine the best method of making timely distribution of critical weather information, even at the expense of less crucial low priority items that are not time sensitive.

It must be recognized that critical review of circuit priorities is not a solution of basic teletype circuit capacity limitations. Means exist to increase circuit capacity and should be brought on line as soon as possible so capacity can safely meet demand.

There is a requirement to determine the optimum mix between broadcast weather information and discrete address response to specific weather questions. If automatic weather observation is implemented widely, broadcast dissemination would be an inefficient use of radio frequencies. The best way to avoid radio frequency congestion would be to provide pilots with the means to specifically request the weather of interest to them and to receive only that weather in response.

The deficiencies in observing weather by existing surveillance radars are recognized and controllers are understandably reluctant to provide weather advisories based on their observations. Research and development efforts are required to provide useful real-time weather displays to controllers, including the provision of specialized weather sensors. Complementary efforts should be undertaken to train the controllers so they can provide more precise advisories for the avoidance of severe weather.

2.2.3.6 Expected Benefits

Better weather information, including more observation points, improved forecasts, greater accessibility and improved dissemination will provide many benefits leading to improved utilization of aircraft and the airspace, as well as enhancing safety of flight operations. Fuel conservation will result, aircraft

utilization will be improved, schedules and flight planning will be more accurate and reliable, and the practical capacity of the airspace system will be less subject to restraints otherwise imposed by inadequate weather information.

2.3 Special Use Airspace

The following are categories of Special Use Airspace:

- Military Training Route (MTR)
  - Instrument Routes (IRs)
  - Visual Routes (VRs)
- Restricted Areas
- Warning Areas
- Prohibited Areas
- Military Operating Areas
- Alert Areas
- ATC assigned airspace (stationary or moving)

A comprehensive analysis of the volume or area of airspace designated for special use is presented as Appendix B of this chapter.

All special airspace designations, air traffic control procedures and regulatory airspace actions can generally be classified as having some constraints or effect on one or more classes of users of the airspace. On the other hand, some users are constrained by procedures and regulations to conduct certain operations in designated special use airspace areas because of the incompatibility of these operations with other uses.

When developing procedures, rules and designating airspace, the FAA must take into consideration the following:

1. Safety - for all users (separation assurance)
2. Manageable traffic flow to prevent potential for midair collisions.
3. Environment - minimize nuisance impact of noise.
4. Economic - impact on use of fuel and cost to users.
5. Practicality - compatibility with ATC system versus mission accomplishment.
6. Compatibility and impact on other users.
7. Importance of mission.
8. National security.

In order to properly assess the impact the airspace action (regulatory and precedural) will have, the FAA should quantify the extent of impact for each class of user before making the final decision.

To further aid the information process as to impact on other users, FAA utilizes the following process: Advance Notice of Proposed Rulemaking (ANPRM), Notice of Proposed Rulemaking (NPRM), direct meetings with users, coordination within FAA (i.e., Flight Standards Service, Airway Facilities Service, Office of Airport Programs and Air Traffic Service) and operation reviews (public hearings). The entire process places the FAA in the position of a judge as to what impact or constraint will be levied on the users after considering the whole picture.

Keeping in mind that the ultimate system must ensure that aircraft in the system, be given maximum assurance of reaching destination without encountering the undue hazard of a midair collision, the E&D effort should be directed to resolving incompatible operations within the airspace in order to minimize constraints to freedom of the airspace. This can best be accomplished by developing better communications and coordination procedures between ATC, special use airspace users and constrained users in order to achieve the objective of better utilization of the airspace.

2.3.1 Constraints Due to Special Use Airspace

2.3.1.1 VFR Operations

Military Operations Areas, Training Routes and Warning Areas impose no penalties on VFR operations other than the necessity to exercise extra vigilance when transiting such areas.

Some Restricted Areas preclude VFR operations entirely or VFR operations therein are precluded procedurally by ATC jurisdictions even though "joint-use" conditions permit such operations with ATC approval.

Prohibited Areas cannot be utilized for VFR operations. However, due to the limited number of such areas VFR operations are not significantly penalized.

The confinement of military tactical training to charted special use airspace only, imposes severe operational constraints on military commanders. The specific dimensions of special use airspace coupled with overland supersonic flight restrictions severly limits the type of training that can be conducted in such airspace. In addition, the requirement to conduct high speed low level training to a limited number of military training routes causes overfamiliarization with those routes and degrades the quality of such training.

2.3.1.2 IFR Operations

Special use airspace often creates severe operational problems for flights that are required to operate under Instrument Flight Rules regardless of the

weather, (e.g., the scheduled airlines), or users that elect to do so in order to receive specific ATC services. As a result, the costs of such operations are significantly increased. In addition, though the related safety impact on such operations is difficult to define, special use airspace increases air traffic congestion (controlled and non-controlled) around the periphery of these areas. Operational flexibility with regard to selection of desired "weather" routes is reduced, and ATC workloads adjacent to or through such areas increases. These problems are further complicated by the variable "moving block" type of special use airspace.

Operational penalties due to special use airspace include almost every phase of flight planning and flight control to destination for potentially affected flights. Initially, significant flight planning problems arise due to the inability of the ATC system to provide accurate timely information to pilots/dispatch offices on the current and projected status of special use airspace pertinent to the planning of a specific flight. Without such information, a significant planning variable is introduced which is difficult to reconcile with other flight planning factors, e.g., weather patterns, fuel loads, etc. As a result, more fuel may be carried than required, optimum weather patterns may not be selected and circuitous routings or less desirable altitude/flight levels may be planned.

The above flight planning functions pertain in total or in part to special use airspace that varies in availability to other uses. With regard to "exclusive" special use airspace, the above penalties apply on a routine basis but the related flight planning variable is essentially eliminated.

Further, after flight planning is completed, utilizing supposedly correct information on special use airspace and the plan is filed with ATC, it is sometimes discovered that the Air Traffic Control Facility responsible for issuance of the departure clearance rejects the routing or reroutes the flight because the facility has incorrect information on the status of special use airspace or the routings desired by downline ATC facilities due to such special use airspace. In other instances, ATC facilities issue revised routings due to other air traffic problems which increase the impact of special use airspace on a particular flight. Situations are encountered en route that could have been avoided, or their impact reduced if the ATC system had offered alternative routings prior to flights reaching a position which required excessive rerouting with attendant fuel, distance and time penalties.

ATC system route designs are significantly affected in many areas by the existence of special use airspace. FAA designated routes are established to avoid special use areas with the resultant loss of independent and/or direct routings and the "bottle-necking" of major traffic flows in areas often far removed from such special use airspace. This is compounded by ATC's use of preferred routings to

organize traffic flows at the flight planning stage. To specifically quantify or measure the impact of special use airspace in this sense is difficult but examination of designated routes between major hubs will clearly indicate the problem in the vicinity of special use areas.

Bottle-necking around special use airspace adversely affects all users of the National Airspace System. Concomitantly, this effect also "boxes in" special use airspace and limits future expansion of such airspace to contain the increased space requirements of higher performance aircraft.

In recent years, improved navigation equipment has provided the capability in varying degrees for flights to operate point-to-point with high accuracy along so-called "random" routings by use of self-contained/refined navigation systems. The capability permits selection of optimum routings subject only to the availability of the airspace and related ATC clearances. Studies accomplished as a result of work done by an FAA-Industry Task Force on RNAV clearly indicates the routing penalties placed on users equipped with an RNAV capability by such special use airspace. Even without this capability, many direct route segments available within prescribed navigation parameters or with use of radar techniques are denied because of special use airspace.

Examples of the penalties experienced by a major user, the airlines, should be noted with regard to the east coast off-shore warning areas and some of the large restricted areas in the western part of the United States.

2.3.2. Means to Reduce, Relieve or Remove Constraints of Special Use Airspace

2.3.2.1 Procedural

Current FAA procedures provide an adequate base for maximizing the availability of all special use airspace to other airspace users. However, there are a number of techniques associated with the application of existing procedures that must be treated in order to reduce special airspace use contraints. These include proper and timely coordination and exchange of accurate information between special use airspace users and the operator of the ATC system, timely dissemination of such information to concerned users of the ATC system and continuing ATC planning "ahead of" controlled flights to determine the impact of special use airspace. Procedural relief potentials are defined between FAA and the Special Use Airspace users, and should be rigidly adhered to by all parties. A contingency procedure should be developed when possible to permit use of special use airspace in a specific instance when unusual conditions warrant it.

In particular, from the standpoint of VFR operation, procedures should be applied by ATC jurisdictions to permit passage of such operations though "joint-use" airspace.

Special use airspace must be effectively managed and returned to FAA by the military when not in use. Records of military use of such airspace must be accurately maintained to justify expansions or reductions of such airspace. FAA must ensure that "joint-use" airspace is made available immediately to other users when released by the military.

2.3.2.2 Regulatory

FAA and special airspace users must continue to limit designation of special airspace use to a minimum and to maximize joint-use of such airspace wherever possible. Relief action should be concentrated on determination of special use airspace activity pattern requirements and obtaining release of such airspace at other times. Pattern adjustments on usage, particularly where other special use airspace exists in the general area, should be attempted in order to minimize the impact. More emphasis should also be given to use of stratification through such areas where possible.

2.3.2.3 Technical/Innovative

Immediate - Refinement of existing programs to further bridge the gap between military mission control and air traffic control, including: maximum joint usage; standardization of procedures for call-up and release of airspace; the dissemination of real-time usage to the aviation public; and a vigorous pilot education program. Require direct contact between the using military command or unit, and the controlling ATC Center to permit better utilization of restricted airspace when not in military use. Develop ATC procedures to handle requests from VFR traffic for clearance through "joint-use" airspace where possible.

Users of the airspace should familiarize themselves with published procedures pertaining to use of special use airspace.

Long Term - Centralize scheduling and control of all special use airspace on an area, regional or national basis.

2.3.2.4 Results, Expected Benefits

Benefits will be achieved by both military and/or civil users as follows:

1. Fuel will be conserved.
2. Operational safety enhanced.
3. Operating costs reduced.
4. Capability to provide improved flight planning will be increased.
5. Maximum flexibility for the use or release of special use airspace will be provided.

6. Greater advantage can be taken of desired weather routes.
7. The potential for using desired altitudes and routes is increased.
8. Pressure against establishment of special use airspace may be lessened.

2.4 Airspace - ATC and Supplementary or Alternative Management

2.4.1 Introduction

A summary discussion of the work of Topic Group 3 on the subject of supplements or alternatives to ATC management of the airspace is presented in Sections 1.2.4 and 1.3.4. Background documents for these summaries appear in Appendix C to this chapter and are limited to those documents which were most important in guiding the committee towards its conclusion. A new air traffic control procedure called Electronic Flight Rules (EFR) was conceived which seems capable of eventual implementation and would serve to expedite traffic with safety in certain portions of the airspace.

2.4.2 Electronic Flight Rules

A concept for a new flight procedure under IMC conditions called Electronic Flight Rules seems (EFR) feasible in airspace that is under the surveillance of DABS interrogators for those aircraft which become equipped with DABS transponders. This procedure would ultimately, in its simplest avionics implementation, permit a DABS equipped aircraft to fly under IMC conditions without necessarily filing any or a complete flight plan in airspace that was under DABS-type surveillance where the traffic density is sufficiently low so that knowledge of aircraft intent is not essential at all times for separation safety. There would be no limitation to the use of this same airspace under IMC conditions by IFR qualified pilots in precisely the way they use the airspace today.

A DABS equipped aircraft and pilot flying EFR must be qualified to fly under IMC conditions and must abide by the terminal procedures in effect at the origin and destination of his flight. En route separation from aircraft flying either EFR or normal IFR procedures is provided either by the DABS/ATARS operating in a traffic separation rather than collision avoidance mode or by an AERA type en route center computer. When the projected flight vector of an aircraft flying EFR procedures is computed in the ground system to come within an "avoidance volume" of the projected flight vector of another EFR aircraft or that of an aircraft flying normal IFR procedures, a data linked message is transmitted to either both EFR aircraft or the single EFR aircraft, and the controller responsible for the IFR aircraft. The data linked message to the EFR aircraft contains a traffic advisory and perhaps a request for flight intent or a temporary maneuver restriction or instruction that will prevent the two aircraft from occupying the "avoidance

volume" simultaneously. In the case of an interaction with an aircraft flying IFR procedures, only the EFR aircraft receives the data link message. In the case of an interaction between two EFR aircraft, both receive data linked traffic advisories and perhaps cooperative temporary maneuver constraint or instruction to prevent the two aircraft from occupying the "avoidance volume" simultaneously.

The practicality of such a procedure in any airspace depends on the relationship of the "avoidance volume" to the traffic density and the aircrafts' capabilities and therefore the rate at which traffic advisories and clearances have to be transmitted to aircraft flying EFR procedures. Therefore additional analysis is required to determine the practicality of EFR.

The EFR procedure, as described, seems to satisfy widely held points of view:

1. EFR must be capable of evolutionary implementation; i.e., the equipped user must be able to realize benefits of EFR without equippage of all aircraft using that airspace.

2. There must be no derogation in the safety of conventional IFR operations.

Should such an EFR procedure become practical, the anticipated benefits are:

1. There would be decreased dependence on conventional IFR ATC procedures by EFR-equipped aircraft.

2. The aircraft operator would save time and cost as compared to present IFR procedures where flight plans must be filed and approved by FAA.

3. FAA, by gearing its requirements for information on aircraft intent to the level of control needed to maintain safety, can expedite flight under IMC conditions at lower costs.

Some Possible Extensions of EFR

While EFR is focused primarily on allowing uncontrolled operations in IMC with little or no controller intervention, it should be able to provide increased safety in VMC as a backup to VFR procedures in airspace under DABS surveillance. In other words, the ground ATC system can operate in a traffic avoidance, as well as collision avoidance mode under VFR as well.

EFR might be feasible before DABS surveillance is available. An aircraft equipped with an altitude encoded ATCRBS transponder might fly EFR, receiving traffic avoidance instructions by VHF to avoid IFR traffic. The pilot would have to

monitor communication channels, however, so the reliability of the communications link, and the controller work load if it is a manual system, would require careful analysis to determine the safety of EFR with this level of equippage.

EFR would require that the original DABS transponder be installed with antenna diversity. Thus the user community is faced with a choice - if it wants EFR in non-surveilled airspace or a low-cost CAS backup sometime in the future - it might wish to buy a somewhat more expensive DABS installation now. If it never wants an EFR capability in non-surveilled airspace or low-cost CAS, it could buy the less expensive DABS installation.

Recommendations for E&D Initiatives

1. Evaluate EFR procedures in the DABS environment.

2. Evaluate various extensions of EFR:
   a. to the current ATCRBS environment;
   b. to currently non-surveilled airspace using airborne collision avoidance systems, or by low-cost extensions to the DABS ground environment.

2.5 Navigation Aids - Adequacy of Coverage and Accuracy

2.5.1 Definition of Constraint

The coverage and accuracy of navigation systems are limited depending on the system being utilized. These limitations govern the application of separation standards in the lateral dimension and place other constraints on the use of airspace. Descriptions of air navigation systems in current use or firmly planned are found in Appendix D.

2.5.2 Means to Reduce, Relieve or Remove Constraints

2.5.2.1 Procedural

While some VOR/DME-VORTAC facilities have been located directly on airports, the majority are sited off airports primarily to serve the en route structure. Such policy coupled with the high cost and limited availability of terminal approach aids at reliever airports has seriously constrained the use of such airports and surrounding airspace in instrument weather conditions.

During the past 10-15 years, the general aviation community has grown at a rapid rate. The number of general aviation aircraft has nearly tripled and the number of general aviaton pilots has almost doubled. FAA forecasts for the next

decade predict that this trend will continue. Provision must be made to make reliever airports more accessible to relieve the growing congestion at some of the nation's major hub airports. This can be done by locating replacement aids and new aids for maximum utility. ILS is not required at every airport, but extension of Area Navigation (RNAV), be it VOR-DME, LORAN-C or other possibilities could give sufficient non-precision and semi-precision approach capability to relieve major airport-traffic congestion.

In addition extension of RNAV concept into the en route airspace can divert traffic from congested airways and relieve the traffic congestion.

The FAA should site any facilities requiring relocation to facilitate maximum coverage and accuracy to enhance the use of RNAV capability without creating new doglegs in the airways. Non-precision VOR approaches, as well as RNAV and "semi-precision" 3D RNAV approaches to general aviation airports should be optimized.

When the LORAN-C system becomes fully operational in early-1980, its signals will cover not only the CCZ and other waterways, but also about two-thirds of the land area of the contiguous 48 states. As a consequence, it is anticipated that LORAN-C will be used increasingly to provide position location information. To extend the coverage for this purpose to the entire contiguous 48 states would require additional stations in the midcontinent.

The number of stations may have to be further increased to provide adequate signals over the U.S., if further studies result in a finding that LORAN-C is an acceptable common system replacement for aviation. This would also be predicated on obtaining national and international agreement for its use.

Operational procedures should be directed to allowing the pilot to make maximum use of airborne navigational capability in preference to the provision of radar-derived navigational guidance, particularly in terminal areas.

2.5.2.2 Technical/Innovative

Technical considerations should be given to the possibility of evolving from a rigid airway/route structure to one of random route or point-to-point method of operation. To perhaps a more limited degree, this same philosophy should be applied in terminal areas. Such operations should be more feasible in the future with the advent of greater automation of the ATC system and improved controller displays.

While it is generally recognized that NAVSTAR GPS has potential application for civil aviation, there is considerable concern about user equipment cost and

operating convenience. However, there may be technical ways to modify or augment the GPS signal structure so that it can fully serve its presently intended purpose but permit substantially reduced user equipment costs and enhanced performance.

By using time-multiplexed pulsed signals on the C/A channel or a separate (3rd) channel, it may be possible to build a user equipment with a single RF channel and detector followed by an all-digital processor built around a micro-computer. With the sort of micro-computer capability on the drawingboards now and with intended availability in the early '80s, one can envision a GPS receiver of cost and operating convenience comparable to today's VOR/DME receiver, but able to provide three-dimensional position accuracy of the order of 100 feet. Time to first fix would be less than one minute with essentially continuous update (fractional-second rate after the first fix).

Obviously, such a capability should be of interest to a wide variety of civil users. It would also seem to be quite valuable to military users since it would substantially reduce the cost of the nonsecure mode military equipments without in any way compromising the performance of the system in the secure mode.

FAA should continue its E&D initiatives in this area. The FAA should be alert to any possibilities of developing a very low cost semi-precision approach aid for uncontrolled and less active airports. It is recognized that the MLS format will be used for precision approaches, but adoption of the MLS format should not preclude searches for less expensive methods of providing some type of approach capability at airports not served by ILS, MLS or RNAV at approach altitudes.

2.5.2.3 Results; Expected Benefits

This Group was unable to agree on a quantification of the benefits of making increased use of airborne capabilities available now and in the future, but found that benefits are expected to include:

1. Reduced controller workload.
2. Increased en route capacity.
3. Increased controller capability.
4. Fuel conservation.
5. Reduced communications.
6. Increased use of uncontrolled airports.
7. Flexibility of operation.

2.5.3 Vertical Separation Above Flight Level 290

The vertical element is a vital component of air navigation. The most obvious application of vertical navigation is in the guidance phase to approach and landing. Topic Group 3 elected not to consider this particular aspect in its navigation concern in the expectation that it will be adequately covered by one or more other Topic Groups. But vertical separation of aircraft above flight level 290 did come under discussion by Topic Group 3. While this subject could be covered under Air Traffic Control or Airspace Management, it was felt more appropriate to include it as a sub-set of the navigation consideration since the problem revolves around the accuracy definition of vertical navigation.

During the very early use of altitudes of 30,000 feet and above by turbojet aircraft, it was established that the accuracy with which the vertical dimension could be measured in these low air density regions was insufficient to safely support the vertical separation of 1,000 feet commonly used in altitudes below 30,000 feet. Ever since this decision, flight levels above 29,000 feet (FL 290) have accommodated traffic on a vertical separation of 2,000 feet. The result of this standard is to reduce the capacity of a given volume of airspace above flight level 290 to half that of an identical volume of airspace below flight level 290. And since turbojet aircraft have optimum performance efficiencies in the 30,000 to 60,000 feet strata, and stratospheric meteorological conditions in that region are frequently favorable, competition for the reduced number of available flight levels is keen. Consider the example of a two-way high altitude jet route on which both flight level 310 and flight level 350 are in use. The new applicant has the choice of climbing to 390 which many turbojet aircraft are unable to do when fully loaded or lumbering along in the energy inefficient strata below 30,000 feet. ATC does its best to ameliorate this constraint by using as many jet routes in a one-way configuration as they can, but this relief is constrained by the accuracies needed for lateral separation. Repeated efforts to review the need for this expanded vertical separation in the light of new air data sensing altimeter technology have not been productive.

2.5.3.1 Means to Reduce, Relieve, or Remove Constraint

1. Procedural: FAA should first determine if, by revising ATC procedures or computer programming, there would exist a sufficient level of safety to reduce vertical separation to less than 2,000 feet above FL 290 without an attendant requirement to specify additional airborne equipment standards. That is, can FAA make better use of the existing automated ATC system to safely achieve a reduced altitude standard by procedural and/or software changes alone?

2. Regulatory: If procedural or software changes will not safely yield an altitude reduction, FAA should then determine minimum airborne equipment standards and survey all users to ascertain cost of retrofit to meet those standards. Thereafter, cost/benefit analysis should be conducted in consultation with all users to determine the cost-effectiveness of implementation.

3. Technical Innovation: FAA should create a Minimum Altitude Performance Specification (MAPS). MAPS would then serve as a rational basis on which to specify airborne equipment that is likely to permit compliance with the performance specification.

4. Benefits: By safely reducing altitude separation standards above FL 290 more altitude levels will become immediately available. Thus more aircraft can be accommodated within the same volume of airspace at more efficient cruise altitudes while permitting greater ATC system flexibility. While the potential fuel savings and increased system efficiency should be significant, an exact quantification cannot be calculated until the amount of altitude reduction possible is decided upon (1,000 feet, 1,500 feet, etc.). Likewise, costs to either the user and/or the ATC system operator cannot be calculated until a determination has been made on the requirements to safely achieve an altitude reduction (procedural change, software change, airborne equipment retrofit, etc.).

2.6 Surveillance Deficiencies and Proposed Improvements

The role of primary radar in en route automation system should be directed toward the detection and mapping of hazardous weather rather than aircraft tracking. Weather detection requires a pencil beam, high frequency, linear polarization, a low rotational rate and perhaps Doppler processing. Those characteristics are not optimum for aircraft tracking. At the current level of transponder equippage there is little requirement to track aircraft by primary radar but there is a need for better weather inputs to both the controller and the pilot. FAA should not purchase new or upgrade present en route radars for tracking aircraft, but should invest in radars designed for weather detection. This policy must not compromise the availability of non-transponder procedural separation in those portions of the airspace where it is currently permitted, nor should the present radar system be discontinued until the new ATC weather radar is commissioned.

It seems clear that the overall aircraft surveillance requirements of en route air traffic control can be better met, given fixed resources, by an all-beacon system augmented by a network of weather radars than by maintaining the present network of long-range aircraft surveillance radars. If this change is to be implemented, specific provisions must be made for handling IFR aircraft with

transponder failure. It will also be necessary, at least for some transition period, to adopt the En Route Air Traffic Control System to occasional routine handling of non-transponder-equipped aircraft and to aircraft whose transponders lack Mode C altitude reporting.

2.7 Communications

Numerous communication constraints exist in today's ATC system. These are addressed in three frequently overlapping cateogries: coverage, speed, and reliability. These constraints are defined, expanded, and exemplified in Appendix E.

Potential means to reduce, relieve or remove these constraints are offered by procedural and technically innovative solutions.

2.7.1 Procedural Means to Reduce, Relieve or Remove Constraints

Various procedural means have historically been applied to reduce, relieve or remove communication constraints.

2.7.1.1 Coverage Gaps

Airspace below which, or outside of which UHF/VHF direct communication coverage exists, is oftentimes excluded from considerations as IFR navigable airspace. In many cases, flight plan filing and clearances can only be obtained over land lines like the telephone or teletype with ATC projected and assigned "off times", and procedural separation criteria are applied until the aircraft can reach a UHF/VHF communication reception altitude or position. Infrequently, "stepping stone" or relayed communications are achieved by transmitting to a third party aircraft or ARINC, and relaying to ATC.

2.7.1.2 Overlaps

Chronic overlapping areas shortly become identified by the users and procedural prohibition against use of the problem frequency is accomplished by ATC by changing to non-overlapping alternate frequencies. The new frequency assignment model should improve this area.[4]

2.7.1.3 Mutual Interference

During peak demand a "waiting list" bunches up to try to get in on a critical frequency, such as ground control. The result is two or more transmitters keying almost simultaneously and compounding the congestion. Additional voice channels are one historic solution, but increased use of alternatives, such as visual signaling, should be considered.

2.7.1.4 Number of Frequencies Available

Careful analysis of the implementation of 720 channel communication capability accomplished over the past few years should support an accelerated use of 25 kHz separated channels in the lower altitude en route sectors and congested terminal areas.

2.7.1.5 Congestion

Stress on the courtesy of listening prior to transmitting in the AIM and flying publications, as well as in the ASRS reports. Some communications procedures have been abbreviated, i.e., clearance to "taxi to an assigned takeoff runway" constitutes clearance to cross all runways which the taxi route intersects except the assigned takeoff runway, unless holding instructions are issued. Others could be: On the first contact with clearance control, indicate the file time and initials. On the first contact with ground control, require a statement of aircraft position, eliminate the requirement of the tower to change departure aircraft to departure control. On the first contact with departure control, state altitude, SID, and transponder code squawking.

Increased use of RNAV and conventional SIDs and STARs would decrease communication congestion, reduce controller talk time, reduce message count, and reduce control instructions. Radar vectoring should be held to an absolute minimum. Use of RNAV SIDs and STARs could further reduce radar vectors and altitude instructions. Publishing VHF communication frequencies and sector boundaries in Jeppeson and NOAA charts would additionally reduce congestion and aid pilots.

2.7.1.6 Complex Definitions, Regulations, Procedures and Phraseologies

The pilot/controller glossary has assisted greatly in defining the intent of certain phraseologies, procedures and regulations. A major effort to simplify the FAR regulations in an appendix similar to the "Driver's Handbook" should be undertaken to improve pilot/controller understanding. The necessity of legally binding court defensible legal jargon is recognized, but the Group was not of the opinion that this is the most expeditious or clear means to communicate this information to pilots and controllers.

The AIM lists restricted weather, FSS and center telephone numbers for contact by public/pilots. The number of active airmen not receiving a current subscription to the AIM and the need to expand dissemination of this information was considered sufficiently important for the Group to recommend some government subsidization of this document to expand the number of active pilots well able to "afford" a subscription. If advisory circulars can be circulated at no cost to the pilot, why not something equally beneficial and pertinent?

In-flight direct flight plan filing through FSS is and should be readily permitted, even though at times they are now discouraged. FAA should establish a procedure whereby a pilot could file an abbreviated IFR flight plan with the controller if the flight was VFR and the weather is deteriorating. The present method of air filing causes delays.

Implement more cockpit flyable SIDs and STARs, and use of the concept of cockpit navigation by adherence to prescribed routes/procedures to accomplish entry into and exit from non-surveillance/communication coverage areas. For example, routing from last en route VOR/DME NAVAID direct to LOM with or without a precedure to the airport without use or need for radar vectors. There is a need to establish procedural arrival and departure routes (SIDs and STARs) which do not depend upon radar vector/direct communication capability but which are procedurally non-conflicting.

2.7.2 Technical/Innovative Means to Reduce, Relieve or Remove Communications Constraints

2.7.2.1 Coverage Gaps and Overlaps

The FAA should sample, define and identify accurately the existing communication coverage gaps where there is a user demand. A SAFI type survey of the existing communication coverage areas, as well as comparisons with theoretical/analytical coverage would be helpful. Particular attention should be given to coverage in and around special use airspace.

FAA E&D should continue effort on:

1. Obtaining additional VHF spectrum.
2. Increased use of 25 kc spaced channels.
3. Cost and need for further channel splitting.
4. Means to provide nap of the earth communications coverage in present gap areas.

Existing national policies do not provide clear cut objectives, plans, programs, funding and timetables to correct deficiencies. There is presently

no overall plan to improve the communication system. There are efforts to put in more reliable switching equipment on the ground which will require less maintenance. Presently, in some cases, 43 relays must close when the controller pushes a mike button.

The Discrete Address Beacon System (DABS) will provide a data link capability. This capability could be used to unload the VHF channels in busy areas for some mutually agreed upon functions.

There is an overall RNAV implementation policy and plan, but little funding or manpower to accomplish it and obtain the benefits in communications which would result.

2.7.2.2 Establishment of More Public Use SIDs and STARS

Both preplanned conventional, and RNAV SIDs and STARs improve flight safety. If everyone is on radar vectors and the conflict alert and M&S automatics fail, or communication jamming occurs, confusion and conflicts ensue. If everyone is on a prescribed SID or STAR, the pilots know what to do next and safety is enhanced.

One author has shown that conventional 3D profile descents can reduced communication congestion by 37% and enhanced fuel economy by 11.6 to 13.1%.[5] There are further studies documented to show that 3D RNAV SIDs and STARs could reduce communication congestion by 33%, reduce altitude instructions by 71%, control instructions by 54% and controller radar vector workload by 93%. Controller productivity could be increased 10% in the terminal areas and conflicts en route and in terminal areas could be reduced by 25% while reducing time in the system by 6%.[1, 8] 4D RNAV could provide ±2 second FAF delivery accuracy;[7, 8, 9] and handle 35% more traffic and reduce holding by 30%.[10] While there is dispute over the attainability of system capacity gains in the amounts claimed, there is sufficient agreement that the concepts will be productive to justify further implementation and test by FAA.

2.7.2.3 Establishment of More RCOs

Reduce arrival and departure delays at non-tower airports in IMC weather.

2.7.2.4 Establishment of DABS Data Link

DABS provides improved surveillance accuracy and reliability. The integral data link can permit communication of all the services listed below, plus any others that the users might think useful.

1. Tune VHF radio automatically.
2. Transmit clearances.
3. Transmit radar vectors or 4D time slots and maneuvers (parallel offsets and "direct to's").
4. Transmit traffic advisories and conflict resolution maneuvers if required.
5. Transmit ATIS, NOTAMS and similar information.

In conclusion many communications constraints have been identified. Short and long-term means to reduce, relieve or remove these constraints have been offered. Inability to communicate when and where desired in a timely fashion due to many reasons; lack of standardization and brevity; and very high costs to establish and maintain suitable and adequate communications improvement policy, plans, funding or schedule has been identified as a deficiency. Procedural, regulatory and innovative technical solutions are advocated which can be implemented to reduce these deficiencies.

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9/ "Cockpit Displayed Traffic Information Study, The Boeing Commercial Airplane Company, Final Report DOT-FAA OSEM D6-42968, September 1977.

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2.8 General Aviation Airports

As of December 31, 1977, there were on record in the United States 14,117 airports, heliports, stolports and seaplane bases. Of these, 11,713 were in the airport category.

In the airport category, 3,999 were publicly owned and open to the public. Another 148 were publicly owned but closed to public use. In the privately owned class, 2,335 were open to public use and another 5,231 were available only for private use subject to permission from the owner. Thus, private owners are contributing 35 percent of the national airport system open to public use in the United States. It is significant that these privately owned airports are not eligible for Federal ADAP money under the existing statute.

2.8.1 Lack of General Aviation Airports as a Constraint

The lack of general aviation airports can be considered both as a constraint to freedom of use of airspace and as contributing to airport capacity problems in major metropolitan areas.

FAA airport data for the years 1969 through 1977 indicate that we have been losing about 36 public-use airports per year. This means that airplanes based at public-use airports, which are closed, must find a home base at some other airport. The problem is further expanding through the manufacture and sale of some 14,000 general aviation aircraft per year. When a public-use airport closes, and especially in major metropolitan areas, often the only solution open to the based aircraft owners is to move to the central major airport or to other crowded reliever airports.

The recent report by the Department of Transportation entitled "Potential Closure of Airports" estimated that fully 40 percent of the privately owned airports available for public use are expected to close within ten years.

2.8.2 The Penalty of Inaction to Provide Adequate General Aviation Airports

The continued loss of general aviation airports already is having adverse effects on efficient utilization of the airspace and will impact the airports used by the air carriers in major metropolitan areas more and more as time goes on if an effective program is not undertaken to alleviate the situation.

The impact could have several forms, including increased delays due to increasing demand for use of the airport and the airspace in the terminal area, higher prices for terminal ground space and services, and possible quotas to limit the amount of traffic.

Means to Reduce, Relieve or Remove Constraints

2.8.2.1 General Aviation Airports

2.8.2.1.1 Recommendations

An action program to correct the growing inadequacy of general aviation airport facilities is required on a number of fronts involving the FAA, the users, state and local officials and the Congress. Courses of action to explore include:

1. An aggressive program for retention of privately owned, public-used airports. Tax relief for the public-use portions of such airports should be a part of this program. Provision also should be made for these airports to be eligible for Federal airport funds contingent on suitable assurances that the airport will continue to be available for public use.

2. Joint civil-military use of military airports where feasible.

3. Conversion of surplus military and government airports to civil use.

4. A major effort to improve existing and to build additional general aviation airports in major metropolitan areas and elsewhere as warranted, including facilities for servicing, instrument approach capability, weather observations, transportation, weather briefing and other ancillary services.

5. Increase the capacity of airports used jointly by the air carriers and general aviation wherever possible through the construction of short parallel runways to handle the average general aviation traffic and commuter traffic.

6. A comprehensive public information campaign under FAA leadership and encouragement to inform the public at large of the benefits that airports bring to the nation as a whole and to communities in particular. If this is

understood by the general public, support of airports would materially increase and at least some of the existing feeling that airports are a nuisance would likely disappear.

While most nonaviation people understand the role of the scheduled airlines, it is obvious that all do not understand the complete role of general aviation in our American way of life. This is important if we are to get support for reliever and other general aviation airports. A few examples follow.

Our food supply is enhanced by aerial spraying and dusting, flying fish spotters enable a better supply of fish for our tables, pipeline and powerline patrols ensure that our energy supplies will keep flowing with the least possible interruption due to breaks or leaks, and oil drilling platforms offshore are serviced by helicopters carrying personnel and critical supplies, helicopters of general aviation provide highway patrol reports for motorists and police, forest fires are fought by a variety of general aviation services and forests are seeded and sprayed to give America a better supply of wood.

Banks use general aviation to speed interchange of checks and obligations, medical services of a great variety utilize general aviation for things like rushing patients to major medical centers, getting serum to places where it is critically needed, transporting specimens for analysis and taking doctors to areas where their services are needed quickly on an emergency basis. Engineers are flown to fix time-critical machinery along with needed parts, businessmen are able to reach places on a timely basis that cannot be reached by an airline. Perishable goods are moved from producer to consumer, mail and express get to every corner of the country including places not served by the airlines.

And then there is the matter of recreation. For some time, there have been people who have disparaged general aviation flying that is not connected with a business. The inference has been that this is something bad or unnecessary. Yet, our citizens and our government spend a lot of time and money on developing recreation facilities that often are used by only a small part of the population. Recreation is a big business in contributing to the economy of our country. Personal transportation by private airplane is somewhat like personal transportation by car with some exceptions. The airplane can take you to vacation and tourist spots that cannot be conveniently reached by car or commercial carrier. For some, flying is a relaxation and a recreation just as much as skiing , visiting national parks, fishing or other activities are to other people. This, like all other facets of general aviation, contributes to the national economy, providing jobs for people and income for communities.

7. The provision of instrument approach capability, remote radio outlets that permit direct contact with ATC from the airport surface and other aids will do much to enhance the usability of many existing general aviation airports, thus increasing their attractiveness to users who otherwise have no alternative but to use the major airports. This increases utility and provides additional capacity in the system.

2.9 Helicopter IFR - Operating Requirements

Today there are somewhat over 6,000 helicopters in the U.S. civil fleet. Of this number, 55% are engaged in commercial operation, about 30% in business and corporate activities, and 15% in government related work.

In the last few years, the helicopter fleet has been growing at an annual rate in excess of 12%, nearly three times the rate of growth of the total general aviation fleet. Industry forecasts estimate a helicopter fleet of over 10,000 by the mid-1980s, with about 5,000 of this number capable of IFR operations in instrument meteorological conditions. By 1987, industry sources project over 200,000 helicopter IFR operations per year in the northeast corridor alone.

Operational requirements for helicopters frequently favor low cruising altitudes to avoid headwinds or icing conditions and optimum fuel conservation. This imposes a need for low altitude coverage of communication, navigation, and surveillance signals so that helicopter operators may enjoy the full benefits of participation in the ATC system. There may be areas where such coverage is justified hundred of miles out to sea, or down to the surface of certain areas of land or water.

Since many of the helicopter missions will be over low density routes to infrequently used destinations, ATC services by line of sight station referenced systems will not always be justified. Communications beyond VHF coverage will need to be supplemented, perhaps with HF or eventually satellite-based area coverage. Navigation service beyond the range of line of sight facilities can be supplied by VLF/Omega, LORAN C, or satellite-based systems as appropriate. And in areas where surveillance coverage is not feasible, procedural separation should suffice for adequate ATC management.

Because of the shorter range of the helicopter mission and the need to land almost anywhere, RNAV offers even more dramatic benefits than it does to fixed wing aircraft. But the coverage limitations of VHF station referenced navigation signals make helicopter operators strong advocates of a high accuracy system with global coverage, providing RNAV without the need for point-reference navigation aids. The accuracy of en route navigation should be adequate for standard IFR operations and capable of supporting route widths of two nautical miles or less each side of centerline where necessary.

Navigation aid for helicopter instrument approach and landing is uniquely different from that for conventional fixed wing aircraft. Efforts to adapt the helicopter flight characteristics to a conventional ILS approach procedure constrains both the helicopter and the conventional traffic flow. Alternate or supplementary precision approach guidance such as that offered by the high selectable glideslope angles of MLS will assist in relieving this constraint. And at remote sites unique to helicopter operations special portable or low-cost landing aids, such as airborne radar used with reflector arrays or heliport transponders, should be developed and standardized.

Appendix G presents two definitive statements by Glen Gilbert, who represented the Helicopter Association of American in the work of Topic Group 3. The first paper is his statement before the House Committee on Transportation, Aviation and Weather, September 27, 1978. The second paper is his statement before the FAA/NASA Global Positioning System Seminar of October 17, 1978.

APPENDIX F

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NEW ENGINEERING & DEVELOPMENT INITIATIVES -- POLICY AND TECHNOLOGY CHOICES

CHAPTER IV

SAFETY AND FLIGHT CONTROL

Topic Group 4

Final Report

Topic Group 4: Safety and Flight Control

SUMMARY

The purpose of this summary is to provide an overview of the subject areas considered by the members of Topic Group 4 and to summarize the conclusions reached and agreed to by all active participants in the Group activities. Some of the conclusions, and in certain cases even parts of the discussion, as presented in the Final Report of Topic Group 4, have been carefully worded to achieve consensus, whenever possible. The reader is cautioned, therefore, not to depend entirely on this summary for the results of Topic Group 4's work, particularly on critical issues. For a precise understanding of the Group position the full text of the report should be consulted.

Discussion

The subject matter of Group 4 was outlined primarily by the original FAA work statement, however, it was somewhat modified and more precisely defined in early Group deliberations. Detailed discussions were held on issues of safety standards, separation assurance, approach and land safety, weather, wake vortices, data link, and pilot training. Many of the safety problems in these areas were considered to be in a category other than E&D, such as an acceleration of the purchase and installation of present-day equipment. Only those issues in each subject area which affect FAA E&D were examined in detail.

The discussion of safety standards focused on the need to allocate E&D resources primarily on a cost-beneficial basis with proper consideration for the differences in the appropriate level of costs and desired benefits which exist from one segment of the aviation community to another. There was concern expressed over the possible adverse effects of improperly using numerical goals for reliability of systems and the consequences of confusing safety goals and reliability goals. The concept of numerical methods was not in itself considered inappropriate, however, the data upon which such calculations are made and the applications of the results can lead to improper conclusions. No specific E&D initiatives were recommended in this area with the exception of increased emphasis on cost/benefit considerations (more specifically lower cost alternatives) as E&D initiatives are developed.

Separation assurance discussions were supportive of DABS development and higher update rates where needed to allow reduced separation while at the same time maintaining high safety levels. One of the most significant conclusions

reached by Topic Group 4 in the area of separation assurances was a redefinition of the role of primary radar. The details of this consensus were carefully developed and should be examined in detail by references to the appropriate part of this chapter.

The Group felt that the participation of the pilot in the ATC separation process through the use of additional cockpit information was an important issue which must be further examined through additional E&D. A specific set of questions were developed to provide guidance for such E&D. Guidelines were also established to assist with the issues of ATC system failures as increased automation is incorporated.

Another major consensus position was developed with respect to backup separation concepts. The roles of DABS/ATARS and BCAS were further refined in group discussions, and E&D recommendations were formulated.

In the discussion of approach and landing safety issues, emphasis was placed on development of lower cost systems to provide more widespread capability. The MLS was endorsed by the group and specific additional E&D on this system was recommended. Because the majority of fatalities are associated with the approach and landing phase of flight more E&D effort is needed in this area.

The use of coupled approaches or automatic landings as a contribution toward increased safety was reviewed in some detail. Many of the practical problems of today's operations, which preclude such approaches, were discussed. In some cases, MLS will alleviate a part of these problems. The FAA was encouraged by Group 4 to examine ways to resolve these problem areas further, and thus encourage a higher percentage of coupled approaches or autoland operations.

The problems of pilot decision making, particularly during the critical phases of the approach and landing were considered to be important E&D issues not adequately addressed by present programs. It was not possible, however, to reach a complete consensus on specific recommendations for E&D work. The position of the Air Transport Association which was different from the remainder of the group has been treated separately. The reader is referred to Section 4.4 of this chapter which explains this issue more fully.

The efforts of Group 4 reaffirmed the conclusion that weather continues to be one of the most critical elements in aviation safety issues. The historical FAA E&D programs in this subject area were found to be seriously deficient, however, recent planning by FAA seems to recognize that fact and establishes a comprehensive series of programs to address all the major concerns. The Group strongly recommends high level FAA attention to assure timely and successful accomplishment of the planned efforts. The availability of accurate and timely weather

information particularly for the general aviation pilot is one of the most critical safety issues. Separation of aircraft from weather which might be hazardous to flight should be a responsibility shared by the ATC system.

Data link offers many potential safety enhancements and its development was strongly endorsed by the Group. The only specific concern which was raised relates to the human factors issue of possible lost information important to controllers or pilots if "party line" communications are replaced.

Human performance and human factors aspects of increased automation are critical safety issues associated with a large part of FAA E&D. Present planning does recognize this issue, but the necessary FAA commitment to carry out the required research in this area is not as clear.

Finally, the issue of improved pilot training was discussed at some length. Particularly, with regard to general aviation pilot training, the Group felt that potential safety benefits of improved training were substantial and that FAA E&D programs were not adequate in this area.

Conclusions and Recommendations

Specific Group 4 recommendations are summarized below. The reader is referred to Section 9 of Chapter IV for further details.

1. E&D resources for ATC en route primary radar development should recognize the preeminence of weather detection and coverage as their objective. This should not eliminate the use of non-radar procedural separation.

2. The backup separation assurance system should be based upon a DABS/ATARS concept in all areas within its coverage and on an active BCAS concept for areas outside that coverage. At this point in time, FAA E&D should also continue development of a BCAS capability which will operate effectively in a full range of traffic environments.

3. Pilot involvement in the air traffic separation process through the use of cockpit traffic information depends upon resolution of several fundamental questions which should receive priority E&D attention.

4. A network of improved weather radar should be developed which will adequately address the specific requirements of the aviation community. In addition, certain needs for weather information can be met through the use of automated surface observation systems. Any E&D necessary to develop that capability should be expedited. The handling of Pilot Reports (PIREPS)

must be modified to more fully utilize the information in forecasting and to ensure that users receive needed information.

5. Techniques for improved pilot training and associated optimum use of training simulators should be further developed through E&D initiatives.

6. Additional FAA E&D is needed to demonstrate the suitability of MLS for use in a wide range of applications and to develop proposed safety standards for its use.

The members of Topic Group 4 consider the review of E&D initiatives to be an important program for the aviation community, as well as for the FAA. Many of the recommendations are supportive of present FAA directions, some provide suggestions for modifications or additions to E&D programs. In every case it is important to maintain a continuing dialogue in order to facilitate implementation of programs and to respond to the changes in demands and environment which are inevitable.

1. INTRODUCTION

1.1 Introduction

At the March 22-23, 1978, FAA Consultative Conference on E&D Initiatives, a mechanism for more detailed public and industry input was announced. If the users wished, working groups addressing various topics would be established to assess E&D policies and would provide FAA with their recommendations. It was also understood that these groups would operate independently of the FAA, although several FAA individuals did participate in the Group meetings. Topic Group 4 - Safety and Flight Control has functioned in a manner consistent with the spirit of independence intended. The contents of this report reflects the collective judgment of the members of this Group.

A suggested work statement was provided for Topic Group 4 (see Appendix B of the Summary Report preceding all the Group Reports). While the Group felt that there were additional safety issues that could be addressed, it was clear that time constraints would limit the Group's activities. After developing an extensive, though not comprehensive list of such topics, the Group members agreed to concentrate their efforts on the following areas:

1. Safety Standards - setting levels, use of numerical assessment, setting priorities.
2. Traffic Separation - separation standards, backup systems, flight control, human factors, surveillance requirements.
3. Approach and Landing - ground equipment for guidance, use of autopilot, human decision making, hazardous weather.
4. Weather Information - forecasting, radar needs, automatic observation.
5. Wake Vortices - measurement, alleviation.
6. Data Link - safety uses, role of voice communication.
7. Pilot Training - teaching methods, simulator use.

FAA E&D reports and briefings by FAA personnel and aviation community experts formed the basis of Group 4's assessments.

The membership of Topic Group 4 represented a cross section of the aviation community. The following indicates the organizational composition of the Group:

1. Associations - AOPA, ALPA, ATA, GAMA, NATA, NBAA and NPA.
2. Manufacturers - Bendix, Boeing and McDonnell-Douglas.
3. Research Organizations/Consultants - Battelle, Economics & Science Planning, MIT Lincoln Laboratory, MITRE, and Questek.

4. Government Organizations - DOD, NASA, NOAA and NTSB.

A listing of specific individuals who participated in Group 4 activities is provided in Appendix A of this chapter. Additional appendices (B, C, D and E) provide selected background material related to subjects addressed in the chapter. The members of Topic Group 4 do not necessarily agree with the content of these appendices, however, the material was found to be useful during discussion of certain issues.

2. SAFETY STANDARDS

2.1 Introduction

Three specific safety topics were examined by the Group: (1) The potential use and limitations of numerical safety analysis; (2) the nature of cost/benefit considerations in relation to safety issues; and (3) guidelines for establishing safety priorities as a part of the E&D process.

A safety standard is a measure of the acceptability of risk. The wide variety of aircraft operations covers a broad spectrum of risk acceptability from acrobatic flying to scheduled air carrier operations.

An analysis of accident data between 1967 and 1973 can be used to determine the historical risk levels or probability of accidents for various segments of aviation and for different phases of flight. The results are summarized in Table 2-1 and Table 2-2.*

Table 2-1

Fatal Air Carrier and General Aviation Accident Probabilities per Flight Hour 1967-1973 ($X10^{-6}$)

User Category	Ground	Takeoff	Landing
Air Carrier	0.243	0.313	00.743
Small Air Taxi	**	0.8	02.43
Corporate/Executive	**	2.06	10.07
Small General Aviation	**	3.83	14.77

**less than 0.01

*"Assessment of Aviation Accident Risk in the U.S. Between 1967 and 1973", Robert A. Rogers, Battelle, Columbus, Ohio, Draft-April 13, 1978.

Table 2-2

Non-Fatal Air Carrier and General Aviation Accident Probabilities per Flight Hour 1967-1973 ($x10^{-6}$)

User Category	Ground	Takeoff	Landing
Air Carrier	1.64	00.899	03.01
Small Air Taxi	2.90	04.87	14.82
Corporate/Executive	6.91	12.98	63.9
Small General Aviation	9.76	23.0	94.67

The estimated accident probabilities are most useful as measures of relative safety. For example, they clearly point out the relatively higher risk of accidents during the landing phase for all categories of users. The data also verifies substantial differences in accident risk levels experienced by the different user categories.

There have been efforts to compare risk levels in aviation to those commonly accepted in other activities including other modes of transportation. In most cases this is not a useful comparison and should not be a part of any E&D program decisions. There have also been techniques developed to calculate numerical risk values which can be translated into expected accidents and/or fatalities over a given time period. There are several issues relative to such analytical techniques and these are discussed later in the chapter.

Simply examining the numbers of accidents is not a complete assessment of the safety problem. There must also be a measure of the consequences of an accident. Studies are being accomplished by the FAA Office of System Plans which attempt to relate the total cost of accidents to specific phases of flight and user categories. (FAA includes the cost of fatalities in these calculations.) As an example, the cost of landing accidents for air carriers during the 1966-1975 time period in 1974 dollars was found to be approximately $677 million. Of this about 50% was in the pilot-related category and 17% (the next highest) in the category of weather-related.

These data seem to indicate that resolving issues related to human factors during approach and landing offers the greatest opportunity for improving safety. That does not necessarily mean that the greatest amount of E&D resources should be allocated in this area. Expenditure of limited E&D resources should be commensurate with anticipated safety increases attributable to the specific E&D project and should not be determined entirely by historical risk probabilities.

2.2 Numerical Techniques

Whether one likes the idea or not, there is an effective value placed on a human life by every safety regulation. If people prefer not to talk about it, that value remains implicit and may even be unknown. If we are realistic, we use an explicit value and then we can approach the safety problem more objectively.

Accident litigation provides one means of placing a value on human life. The public may require those concerned with safety to place a higher value than that, if it chooses to do so. What is important is that single accidents have cost hundreds of millions of dollars in damages so that the economic benefit of improved safety is very great, and, therefore, it becomes a simple matter to justify considerable investment in safety on purely cost/benefit grounds.

The general problem can then be reduced to examining the historical accident record and estimating how the expected number of future accidents, due to the various causes, could be decreased by various safety measures, and comparing the economic safety benefit with the cost of these measures. (One must also consider the possibility of accidents with unprecedented causes if the potential losses are very high). One result of such cost/benefit analyses is that the risk of accident, which is tolerated from different causes, will vary enormously as it does, of course, today. The objective is not to make the contribution to risk of every component of the system (aircraft, crew, surveillance equipment, ATC personnel, etc.) equal, but to make the contribution of each component as small as can be justified economically.

Herein lies a difficulty in rational allocation of resources because the responsibility for regulation (of engines, structure, avionics, ground equipment, air traffic control services, airport facilities, etc.) is very diffuse within the FAA. If those responsible in the various areas do not use the same approach to the problem, then we will take excessive risks in some areas, and excessive economic penalties in others.

The Regulations contain the terms "extremely improbable", "improbable" and "probable". These terms are admittedly vague. The problem is that these terms are used in connection with many different equipments and they actually mean different things when used in relation to different equipment. As a consequence, if a numerical value is attached to these terms one must choose the level of risk which is required of the most critical of these equipments in order not to reduce the level of safety required of that equipment. In so doing, other equipment requirements might be affected in such a way as to create unnecessary economic penalties.

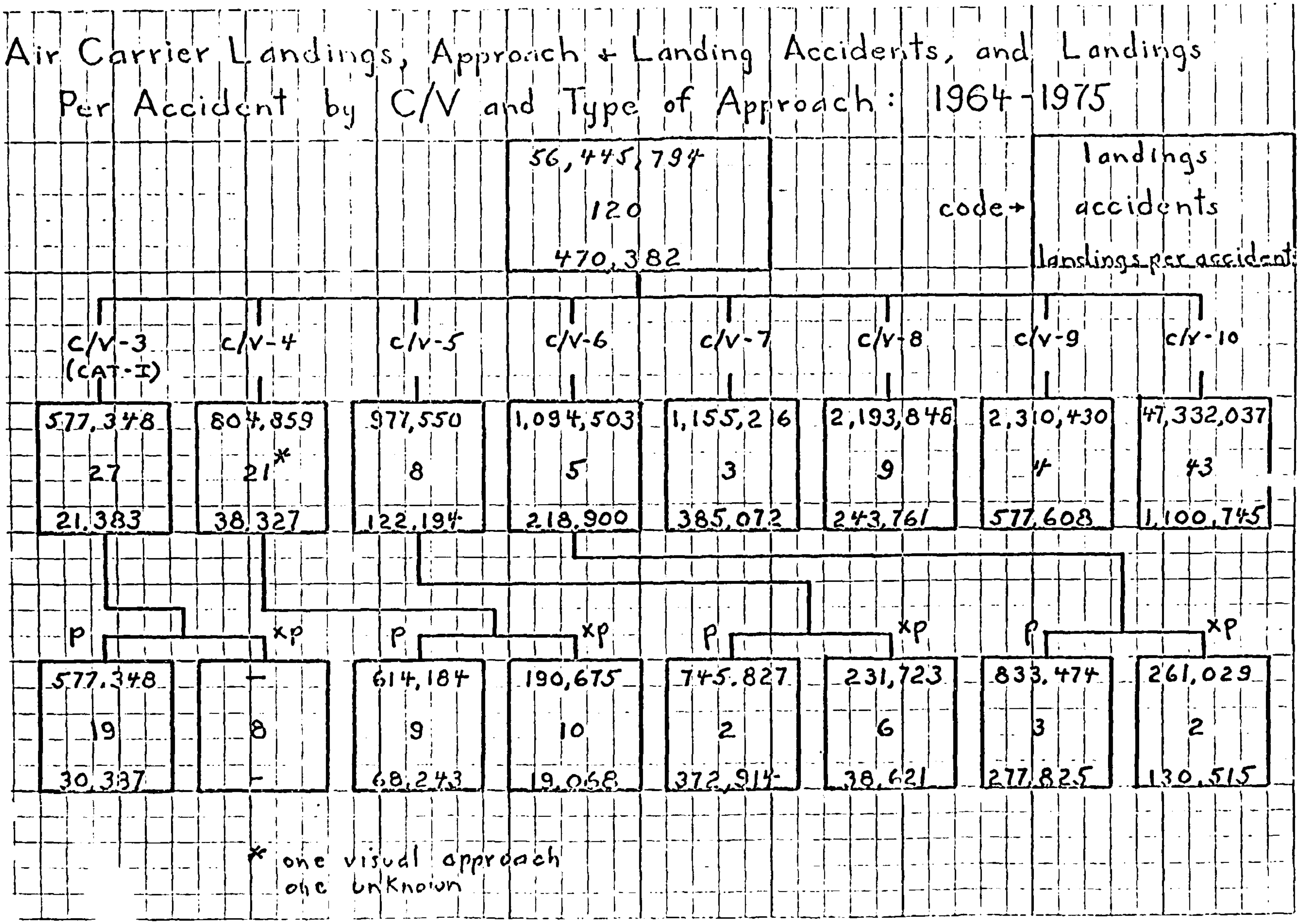
The real effect of quantifying these probability terms would not be so pervasive, however, because the proposed AC contains a "grandfather clause" which states that a probability analysis need only be made "...where a system or its application differs from those with substantial satisfactory experience..." The effect of the AC would be to shift the uncertainty of the meaning of such terms as "improbable" to an uncertainty of the meaning of "substantial satisfactory experience". What it would all boil down to in practice is the acceptance in new aircraft of systems already certificated in old aircraft with a much tougher standard applied for innovations. This preserves the safety we've got at the expense of discouraging improvements in safety and efficiency. This is no small matter. One can forgo both substantial safety and economic benefits by setting unrealistic safety goals for new systems.

The system costs related to the development of first generation autoland systems were very high partly because of the reliability goals which were established. At first glance it might appear that the higher the level of reliability required in aircraft systems the better the level of safety achieved. The return in safety for additional investment might become negligible at some point, but the idea that an excessive requirement can actually derogate safety seems paradoxical and false. Yet this seems quite possible if the reliability of the crew in performing its function as part of the overall system is not taken into account.

In most landing accidents the crew (as opposed to equipment or personnel other than the crew) is held to be at fault. If an automatic system could land the aircraft with one-tenth the accident rate experienced in manual landing then one could expect to save 90% of the lives, injuries, and damage. The term "automatic system" includes many "systems", such as an autopilot, a fail passive autoland, a fail operational autoland system, with and without a Head Up Display, etc. (re: FAA AC 20-57 and 120-28). By setting the requirement for an automatic system at a rate 1/500th that of manual systems one could hope to save virtually all the lives lost, but the cost of such a system can be prohibitive and a ten or twenty-fold gain which would save most of the losses may not be realized because of the costs.

These observations are prompted by a study of air carrier approach and landing accident rates as a function of the type of approach, weather, and light conditions. Figure 2-1 shows the number of landings per accident (the reciprocal of the accident rate) as a function of ceiling/visibility (C/V), and type of approach: (P = Precision, XP = Non-Precision). The upper number in each block gives the estimated number of landings under the specified conditions in the 12 year period of 1964-75. The number in the middle of the block gives the number of accidents under these conditions during the same period. The lower number in each block gives the rate found by dividing the number of landings by the number of accidents. Note that C/V-3 corresponds to ICAO CAT-I: C/V- 4,5 and 6 are increasingly better Instrument Meteorological Conditions (IMC), and C/V- 7, 8, 9 and 10 are

FIGURE 2-1


Air Carrier Landings, Approach + Landing Accidents, and Landings Per Accident by C/V and Type of Approach: 1964-1975
56,445,794
120
470,382
code→
landings
accidents
landings per accident
C/V-3 (CAT-I)
577,348
27
21,383
C/V-4
804,859
21*
38,327
C/V-5
977,550
8
122,194
C/V-6
1,094,503
5
218,900
C/V-7
1,155,216
3
385,072
C/V-8
2,193,848
9
243,761
C/V-9
2,310,430
4
577,608
C/V-10
47,332,037
43
1,100,745
P
577,348
19
30,387
XP
-
8
-
P
614,184
9
68,243
XP
190,675
10
19,068
P
745,827
2
372,914
XP
231,723
6
38,621
P
833,474
3
277,825
XP
261,029
2
130,515
* one visual approach
one unknown

increasingly better Visual Meteorological Conditions (VMC). Figure 2-2 plots these rates and shows a visual fit to the data. Figure 2-3 gives a further breakdown of rates by weather and day and night under CAT-I conditions: D = Day, N = Night, A = Aggravated weather (precipitation and/or thunderstorms), and XA = Non-Aggravated weather. Eight of the 27 accidents in Figure 2-3 occurred when making non-precision approaches, but the combined rate for A and XA precision approaches at night is 11,440 landings per accident. This is a long way from the ten million landing per accident goal set for automatic systems. If an automatic system realized a rate of 500,000 landings per accident and it was used to make all the precision approaches under IMC shown in Figure 2-2 that expected number of accidents would be 5.5, which is a factor of six better than current experience. An automatic system with a landing per accident rate of 925,000 would produce a factor of ten improvement.

The reality is actually more complicated than this. Air carrier precision approach and landing accidents under IMC where the crew action has been cited as a primary cause, fall into four large categories: gross blunders, inadequate visiblity below the decision height, exceptionally adverse wind conditions, and combinations of the last two. The latest state-of-the-art automatic systems are unaffected by visibility conditions and can respond more quickly and precisely to changing wind conditions and so they offer a potential for improved safety over manual landing. One must consider, however, in estimating the accident rate of an automatic system, the joint probability that the automatic system fails at the same time that the pilot loses the required visual cues. One would expect this probability, which is the product of two small probabilities, to be acceptably small. If, for any reason including a lack of confidence in the autoland system by the pilot, a significant portion of the approaches end in a manual landing or go-around, one must reevaluate the overall reliability of the total "landing system". Even if the autoland system reliability is such that there would be one accident in ten-million landings, if a pilot intervenes in as few as 5% of the approaches, then the overall reliability is clearly much less than one in ten million.

Safety goals and reliability goals, though related, are not identical and more recent development of fail passive concepts is a recognition of that fact. Lower levels of complexity and additional utilization of pilot capability can reduce the cost of equipment acquisition and maintenance, while at the same time provide for adequate levels of safety. The setting of safety goals for systems must account for the performance of the crew, as well as the machine to provide a cost-effective result.

The implication of these observations for FAA E&D programs are extensive. The dramatic improvements in aviation safety, which have been realized over the years are not so much the result of more stringent regulations as they are a reflection of technological progress, some of which has been in direct response to

FIGURE 2-2

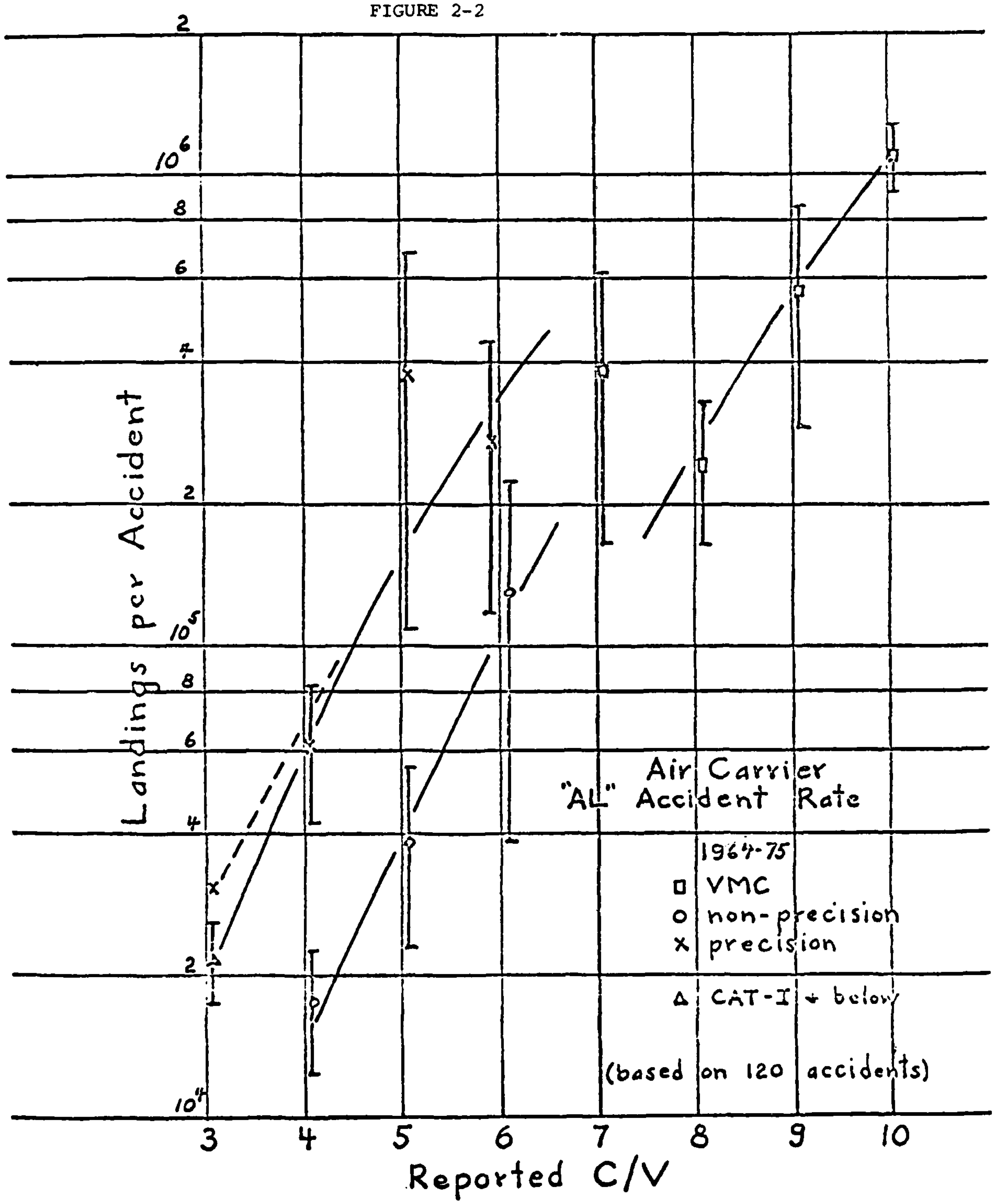
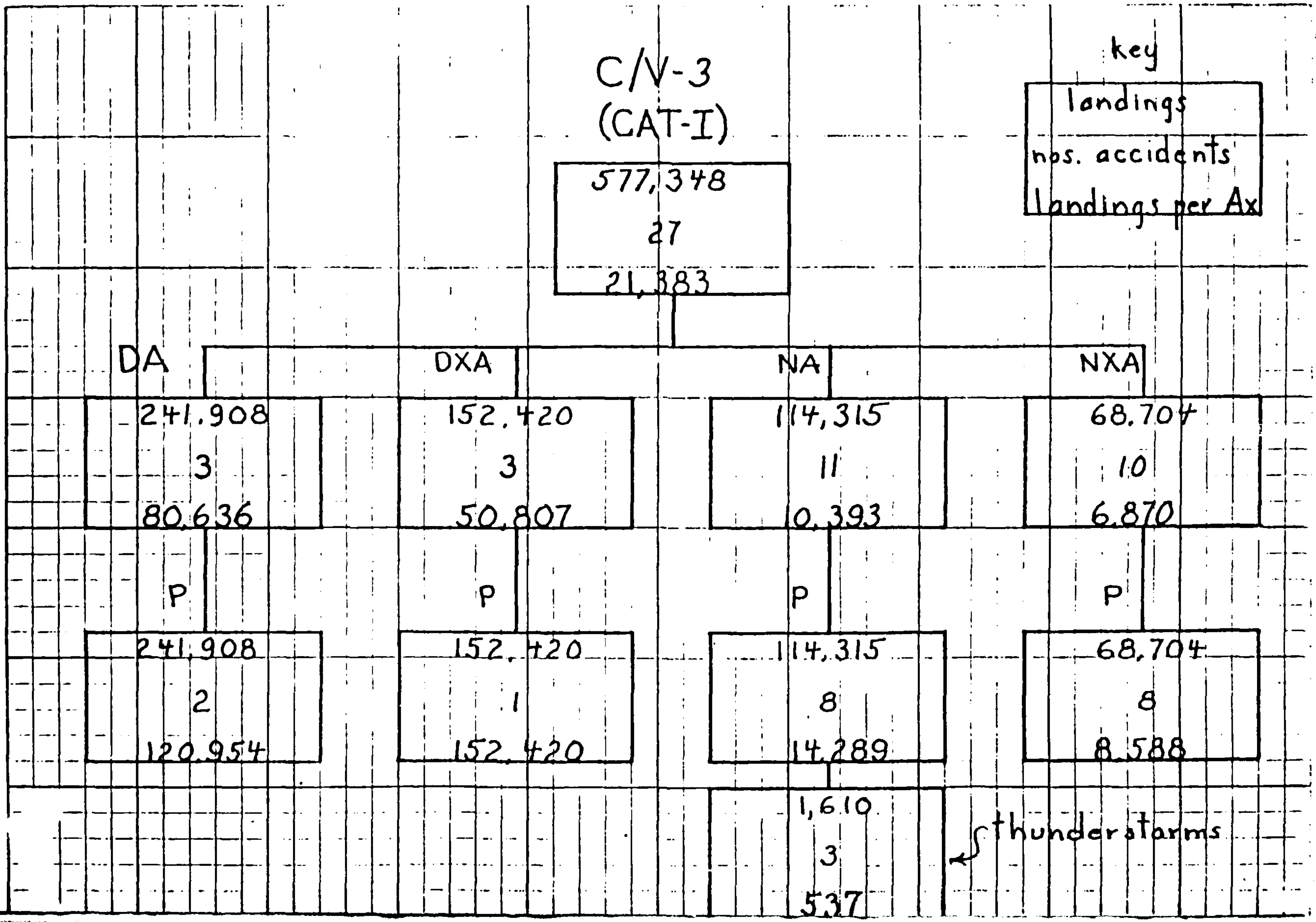

Landings per Accident
Reported C/V
Air Carrier
"AL" Accident Rate
1964-75
□ VMC
o non-precision
x precision
Δ CAT-I + below
(based on 120 accidents)
10^6
10^5
10^4
3
4
5
6
7
8
9
10

FIGURE 2-3


C/V-3
(CAT-I)
577,348
27
21,383
key
landings
nos. accidents
landings per Ax
DA
241.908
3
80.636
P
241.908
2
120.954
DXA
152.420
3
50.807
P
152.420
1
152.420
NA
114,315
11
10,393
P
114,315
8
14,289
1,610
3
537
thunderstorms
NXA
68.704
10
6.870
P
68.704
8
8.588

the needs of aviation (e.g., turbojet engines, instrument landing systems), and some of which has not (e.g., semiconductor electronics, improved structural materials, computers). In some areas the economic potential of new developments in civil aviation is great enough so that the free market produces them, often with some help from the military. In others the economic reward for success is too uncertain, often because of the regulatory process itself, and little progress can be expected from the free market. It is in these areas that it is incumbent on the FAA to support E&D and to allocate its resources intelligently. The FAA can itself use systems design analysis more extensively in deciding what safety and economic benefits various systems could produce, how much should be spent on them, and in choosing among different approaches to safety problems. The result might be a more efficient use of E&D funds and a better record of the actual use of systems developed.

2.3 Cost Benefit Considerations

As discussed earlier, the task of establishing a precise and absolute standard for aviation safety is not only extremely difficult, but of limited value in many cases, for the purposes of E&D decision making.

The level of risk acceptable for each type of operation must be qualified by consideration of what cost increment is required to achieve that risk level. The marginal safety gain is clearly different for the various aviation user elements. In air carrier operations, the very low risk levels which have been achieved can, in many cases, result in very high cost to benefit ratios for proposed changes -- a phenomenon which one would expect given the present risk levels. In some other segments of aviation, the cost/benefit ratio is quite different, however, so is the risk level which is acceptable. E&D program planning should account for these differences by proceding with the development of lower cost systems for certain applications with the knowledge that higher risk levels or operational limitations may be associated with the use of such systems.

Moreover, as mentioned above, determining the area of greatest safety need does not automatically indicate where the majority of resources should be directed. Based upon available technology and probabilities of successful E&D, those resources must be allocated to projects where they will not be wasted. An adequate response to the cost/benefit assessment can affect safety not only by elimination of costly concepts, but also by emphasis on development of relatively inexpensive systems which have significant incremental safety gains. In some cases, the "low" cost system, because it is known to be less capable than already available systems is not developed, with the result that a large proportion of the operations may have no system. The very low cost VASI systems is an example of this.

2.4 Safety Priorities

The relative priority of E&D programs is not simply reflected in budgetary figures or manpower resource allocation. Moreover, there is a reasonably wide difference of opinion with regard to whether a particular program relates primarily to safety, capacity, efficiency, or some other E&D objective. An example of a major program of this type is the MLS development. The degree to which this system addresses safety issues versus capacity or efficiency issues is subject to considerable debate and disagreement.

Another method for analyzing the priority issue is based upon accident data. All generally accepted data points toward a heavy concentration of accidents during the landing phase of operation. In the general aviation community, there is also a major safety concern related to weather information. Although there is no overall agreement, many would say landing safety and weather safety programs do not receive a proportionally high level of priority in FAA E&D. However, this simplistic criteria for priority establishment has certain serious limitations.

E&D dollars should not necessarily be spent in a manner directly proportional to accident rates, but must reflect the expected benefit, as discussed above.

The users have concluded that the recommendations contained in this report will emphasize important existing programs and suggest new areas for work without any attempt to assign a relative priority to each of the elements in the total E&D activity. This is not to say the present priorities are satisfactory to all users, however, the level of detail required to develop a specific, ordered list was not compatible with the level of effort available and there is some question that such a consensus could be reached.

3. SEPARATION ASSURANCE

3.1 Introduction

Accident data shows mid-air collisions continue to be but a small part of the total of aviation accidents and fatalities for all classes of operator, however, the potential for catastrophy has grown substantially with the larger capacity aircraft in use today and the ever increasing density of operations.

The discussion in this section primarily deals with three basic issues. First, the pressures to increase capacity at some locations have prompted consideration of reducing standards of traffic separation which clearly affects safety. As wide body aircraft become more prevalent, the potential losses in a single accident tend to increase which has increased the requirement for more effective backup separation systems. Finally, increasing automation could significantly change the roles and responsibilities of pilots and controllers and impact overall system safety.

3.2 Separation Standards

The FAA's choice of any particular aircraft separation standard has a far reaching impact on both the safety and capacity of the National Aviation System (NAS). In light of existing and projected future user demands on NAS, the pressure to reduce separation standards in the interest of greater capacity is steadily increasing. The main issue in this high growth situation is the degree to which historically high flight safety levels can be maintained through the employment of new air traffic control technology and at the same time allow for reduced separation standards in the interest of increasing NAS capacity.

Effective capacity of NAS is determined partly through the vertical and horizontal separation standards employed by ATC during the departure and en route phases of flight. However, the critical determinant of effective NAS capacity is the mix of horizontal separation standards applied to aircraft during the approach and landing flight phases because of the converging nature of the traffic movement. The final approach air space environment represents the greatest pressure point in terms of the tensions between maintaining adequate safety levels and increasing system capacity through reduced separation standards. It is for this reason that attention in the following subsections is limited to this particular flight regime.

During the approach and landing phases of flight, there is a considerable difference between the separation standards actually governing operations during VMC and IMC conditions. Present IFR separation standards are dependent on a

synthesized judgment of the combined safety margin provided by a 4 second radar surveillance update rate, ILS path following tolerances, airport area communication/navigation aide performance characteristics, and wake vortex dissipation characteristics.

The following observations are offered for use by the FAA during consideration of the ability to safely reduce IFR separation standards through the application of new ATC technology alternatives in the terminal area, approach and landing flight regimes.

3.2.1 Lateral Runway Separation.

A major issue here is how closely two parallel runways can be located on the same airport to permit safe but totally independent IFR landing operations. A major objective associated with a reduction in lateral distance is to provide assurance that two aircraft simultaneously approaching two parallel runways in IMC under IFR rules are not likely to collide during final approach. This involves allowance for a controller/pilot blunder-proof zone after allowance is made for the inherent inaccuracies of the ground-based and airborne systems being used for guidance, as well as surveillance. Major concern here is on the timeliness of the surveillance information provided to controllers and pilots as to the actual, versus intended flight path. This in turn determines the ability to detect a developing unsafe situation and communicate with the aircraft in time to apply corrective flight path action.

The work performed for the FAA by MITRE* in 1975 and M.I.T. Lincoln Laboratory** in 1972 provides an indication of the trade-offs between separation distances and parameters, such as update rate, surveillance accuracy and communication time. The need to minimize the time delay between detection of a dangerously decreasing traffic separation, and action by the pilot to correct that situation is clearly critical and indicates a need for improved surveillance and methods of providing improved cockpit and controller information. The DABS surveillance and data link may be used to provide pertinent information in the cockpit in the most expeditious manner possible.

There may be an interaction between runway separation and missed approach procedures. Unguided missed approaches may not be acceptable at the separations evidently achievable with the high data rate surveillance systems and data link.

The user community will not be satisfied that the present levels of safety are maintained if simultaneous parallel approaches under IMC conditions are conducted with separation below the present 4,300 foot standard until operational tests are conducted which verify the analysis of improved surveillance, operational procedure and cockpit information. One of the objections to reducing separations of

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*"Requirement Analysis for Independent IFR Approach to Parallel Runways at Reduced Lateral Spacing", FAA Office of Systems Engineering Management, November 1975.

**"Parallel Approach Surveillance", M.I.T. Lincoln Laboratory, ATC-13, August 14, 1972.

this type has been the reliability of the controller to detect problems and act without delay. FAA should evaluate the feasibility, potential operational value, and any safety benefit of transmitting separation data simultaneously to the cockpit and controller for these smaller lateral separations. To the extent that a controller or pilot is involved in any future surveillance concept for parallel approach, the reliability of the overall system including whatever human performance is required, must be assessed under realistic conditions.

3.2.2 Longitudinal In-Trail Separation During Final Approach

A major issue here is how closely two IFR aircraft of different weight and speed classes can be positioned safely in-trail on the final approach to landing. This is partly a question of surveillance update rate, as discussed in the preceeding subsection. However, there are additional operating variables to take into account. One of major interest at this time is the impact of wake vortices for the different aircraft weight classes. (See Section 6.) This involves questions of both the presence of hazardous wake vortices and the degree of impact on the need to alter any given longitudinal separation distance. Other areas under current FAA study are wind shear detection and minimum runway occupancy time. In all cases, a judgment of safe separation distance for any given condition (or combination of conditions) is required.

1. All of these considerations should be part of the trade-off scenarios developed for surveillance update rates equal to and faster than once every 4 seconds.

2. Full consideration should be given to retaining a "party line" communication approach, whereby following aircraft can overhear clearances. (See Section 7.)

3. The full impact of potential MLS features such as curvilinear approaches and variable glide slopes should be factored into the assessment of safe longitudinal separation distances.

4. Wind shear above a certain level results in different operational practices, such as additional air speed margins which might affect separation.

5. The use of cockpit traffic information should be evaluated.

3.2.3 Separation in the Terminal Area.

The 21 largest air traffic hubs now employ Terminal Control Area (TCA) operating requirements and procedures. There are presently about 84 large metropolitan areas which employ Terminal Radar Service Area (TRSA) operating

procedures. To one degree or another all of the potentially new ATC technology could impact present separation standards in terminal airspace. Careful consideration of separation distance potential for any given mix of new ATC technology is one of the most challenging tasks involved in the FAA's near-future decision making process.

1. The constraints imposed by a changing mix in the percent of aircraft equipped with ATCRBS and DABS should receive special attention.

2. Although the impact of ATARS on terminal area separation standards has received some real and fast time simulation at FAA/NAFEC, the interaction of ATARS with the ATC system requires additional fast time simulation and extensive real-time simulation to identify fully the nature and magnitude of its impact. The interaction of BCAS with the ATC system must be more fully simulated. Where and when ATARS data should suppress BCAS data for pilot use also requires real-time simulation to assure that the best solutions are offered for initial implementation.

3. Extensive use should be made of NASA's Aviation Safety Reporting Systems (ASRS) data as a means to identify and evaluate the implication of present terminal area ATC technology and procedures designed to provide adequate separation assurance.

3.3 Surveillance Issues

With the increased density of air traffic, a diverse mix of aircraft performance, closer separation standards and higher levels of automation there is a need to assess the capabilities and limitations of the surveillance system to ensure that its performance is compatible with the required levels of safety in the face of these changes.

3.3.1 Design Considerations

It should be anticipated that there will be limits to the amount of Facilities and Equipment Funds available for new surveillance facilities. Therefore, the users feel it is necessary to review the priorities related to the expenditure of additional funds for surveillance and the impact of these expenditures on safety and capacity. FAA now spends much more on the larger and more complex primary radar than on beacon interrogators. This imbalance is heightened when the ultimate utility of the information derived from each is considered. Therefore, it appears imperative at this time to reevaluate the issue of the primary vs. secondary radar.

The traditional positions of various aviation users on this old question have changed substantially. These users now appear to recognize the limitation on

funding and the performance/cost imbalance and appear no longer to be widely separated on issues of the unequipped aircraft, air defense, weather sensing, etc.

The present FAA planning includes a program to update the ARSR radar system to reduce maintenance costs, improve air traffic surveillance capability, and enhance weather detection. Twenty-three (23) new ARSR radars have been purchased, and an additional 91 systems to replace the earlier versions of the ARSR radar, are slated for acquisition. The cost of this program will be more than $300 million.

The FAA plan also includes development and acquisition of a limited number of ASDE-3 systems for airport surface traffic surveillance.

The user groups have reached a consensus position which is based upon the following factors and assumptions:

1. The present network of National Weather Service (NWS) radar will be upgraded.

2. As indicated in present plans, the FAA will modify Airport Surveillance Radar (ASR) in an attempt to enhance the ASR weather detection capability.

3. In most geographical areas, the vast majority of future, en route air traffic surveillance service will utilize secondary radar capability. Terminal areas will continue to use primary as well as secondary radar.

4. Costs of maintaining ARSR systems are growing and will continue to be a substantial FAA O&M expense, even with the purchase of new ARSR systems.

5. Improvements to terminal area primary radar which are necessary for air traffic surveillance will continue.

6. The need for a limited number of primary radar systems for military surveillance may continue.

7. Any other special needs for en route primary coverage, such as those associated with border patrol functions, will be treated as an issue separate from the basic ATC surveillance needs.

Based upon the above a series of recommendations have been developed which are summarized in Section 9 of this chapter.

3.3.2 Maintaining DABS Flexibility

The FAA program to upgrade surveillance capability should be performance oriented rather than product oriented. DABS as defined by its signals in space, link protocol, etc. may provide an immensely effective baseline for future automation upgrading. The DABS sensor in some applications, where higher data rates or special coverages are needed could be based on electronically rather than mechanically scanned antennas. Such sensors may provide increased accuracy, increased coverage and new services (particularly to the airport surface regions) and increased data rate (for effective surveillance of parallel approach routes).

3.4 Cockpit Participation in the Control Process

Many questions have been raised as to the value of having a different form of pilot participation in the traffic control process through the use of additional information in the cockpit. A cockpit display of traffic information (CDTI) is being evaluated by FAA R&D. Users are concerned that the FAA is not investigating this subject area with the priority and appropriate level of resources necessary to answer in a timely manner the following safety questions:

1. Does the use of a CDTI and an associated division of traffic separation responsibility result in safe separation in all situations including those where elements of the ground or airborne ATC systems have failed?

2. Can flight crews safely manage the normal aircraft operations while taking on additional traffic separation responsibility introduced by the use of a CDTI?

3. What safety impact results from various mixes of aircraft with and without airborne traffic information?

4. When a pilot believes (based upon CDTI information) that separation standards are violated, what procedures should be followed?

5. What is the overall effect on pilot and controller workload?

6. What are the relative merits of ground-derived and air-derived data or mixtures of these, with regard to accuracy, update rate, currency of information, failure modes, and cost?

7. How can air and ground derived information be coordinated to minimize different perceptions of a given traffic situation due to differences in geometrics, measurement accuracy, time delay, update rate, etc?

8. How many displayed targets and what type of target information is appropriate and what target parameter are needed?

9. What are the operational impacts of integrating CDTI data with other information, such as weather or area navigation data in an integrated display?

The amount of cockpit participation in ATC is a fundamental system design variable. Therefore, it should be evaluated concurrent with automation.

3.5 ATC System Failures

As the complexity of ATC system design increases, it becomes more difficult to analyze the impact of the many types of ATC system failures. In order to ensure an appropriate level of safety even with failures in the primary separation assurance system, a multi-faceted approach should be taken which will provide the necessary backup capability. Such an approach should be guided by the following:

1. The primary automation system will have redundant hardware and sufficient software provisions to assure that ground system outages are improbable.

2. The automation design will provide for the air traffic controller to act in a supervisory capacity such that he can be in close enough contact with the details of the system performance to be able to provide backup services which will maintain the safety level of the primary system. It will not be a requirement to maintain system capacity or efficiency under such backup circumstances.

3. Utilizing the same traffic data base, the air traffic controller will supervise the system operation with displays, software, and other tools independent of the primary automation system, so that he/she can provide the desired backup capability.

4. An ATARS capability will be provided at each DABS site as a collision prevention backup for aircraft equipped with DABS.

5. A BCAS capability as defined in Section 3.6 will provide a collision prevention backup in the event of a DABS/ATARS outage and in areas not within DABS coverage.

6. Exploration of other complementary backup capabilities should continue. Examples of such possiblities would be overlays of communications and surveillance and uses of current, precomputed backup clearance for aircraft in the event of failure.

The development of an operational system with several complementary elements clearly requires extensive simulation to verify proper operation in a dynamic environment and under all anticipated situations. As a part of the evaluation process analysis of the pilot and controller capabilities and requirements must be made for all types of failure operations. These efforts would, in turn, lead to development of simulation capability for training.

3.6 Collision Avoidance Systems*

A system or systems which are primarily designed to provide backup separation assurance, whether air or ground based, are classified as collision avoidance systems in this discussion. Specifically, a collision avoidance system CAS includes (1) detection of appropriate aircraft, (2) computation of potential traffic conflicts, and (3) computation and display of commands for conflict resolution. A display of traffic information in the cockpit which provides a degree of redundancy is discussed in Section 3.4 of this chapter.

A review of E&D activity was accomplished. The Group members considered: (a) a description of a multimode BCAS that is designed to operate in all airspace and to meet traffic densities expected through 1995, (b) test results of an active only BCAS, and (c) the development of a variety of active only BCAS systems.

A consensus position was developed based upon the following factors and assumptions:

1. The unit cost of the "full" BCAS as defined by Report Number FAA-EM-78-5, Vols. I, II & III is likely to be greater than $50,000, not including installation (directional antennas will be needed).

2. The planned development period, through prototype test and evaluation of the "full" BCAS is 4-5 years, at a total additional cost for E&D development of tens of millions of dollars.

3. The "full" BCAS would be an extremely complex array of avionics equipment.

4. There are active BCAS test results for both the DABS and ATCRBS modes in current high density traffic environments that verify improved tracking capability against aircraft equipped with DABS transponders (top and bottom antennas) as compared to aircraft equipped with ATCRBS transponders (bottom antennas only).

5. A family of active BCAS systems, with capabilities matched to the needs of a variety of users, can be developed in a shorter time period than

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*The Airline Pilots Association (ALPA) does not concur with the position on Collision Avoidance Systems (CAS) expressed in Section 3.6 and in related conclusions found in Section 9. The ALPA position is presented at the end of Volume I.

the full BCAS and at costs to the users - depending on his needs - ranging from $3,000-$20,000, not including installation costs.

6. A ground based separation assurance backup system (ATARS) -- isolated at the DABS sites from failure of the primary control system -- has the capability of providing an effective collision avoidance system within 50 miles of any DABS site. ATARS is designed to have the capability of providing advisories to aircraft which will enhance safety by keeping such aircraft from terrain or restricted airspace. E&D necessary for inclusion of this additional capability should be a part of the ATARS development.

7. Separation assurance backup would require the installation of DABS/ATARS facilities at the 23 high density hubs and at the 37 medium density hubs initially. Ultimately all present and future secondary radar sites including en route, as well as terminal areas should have DABS/ATARS facilities. In airspace not covered by such facilities, active BCAS provides some backup separation assurance.

8. The DABS/ATARS system will have priority over the BCAS within ATARS coverage.

9. Cockpit traffic information could be supplied by DABS/ATARS where there is coverage, and by active BCAS everywhere else. The type and quality of the traffic information provided by an active BCAS is related to its sophistication and cost, for example, the use of an aircraft directional antenna to provide some bearing information in the absence of ground DABS coverage.

The related user recommendations which were developed are contained in Section 9 of this chapter.

3.7 Human Interfaces with Automated Systems

The development of more complex and more automated systems has brought into sharp focus concerns for achieving design of man/machine interfaces which will not derogate safety.

In particular, the possibilities for blunders by either pilots or controllers with today's system, as well as future more automated systems, are of great concern.

As a demonstration of concern for human factors, the scheduled reduction of North Atlantic lateral separation standards from 120 miles to 60 miles has been delayed. During the past eight months since Minimum Navigation Performance Specifications (MNPS) were put into effect, a surprisingly large number of

navigational errors have been detected by radar surveillance. Out of the 13 total blunders, each resulting in more than 50 miles of deviation from track, 4 were classified as equipment control errors or communications misunderstandings. In addition, another 4 such deviations were by aircraft not authorized to fly in that airspace. This latter form of blunder is likely to plague any type of ATC system which attempts to restrict certain users.

Designs of any automated systems must be based upon careful and comprehensive studies of human behavior and error inducing phenomena. In addition, simulations should be used to verify the tolerance of the aircraft separation concepts to human blunders. Adequate safety levels cannot be acheived without E&D efforts on both fundamental issues.

There are several specific E&D areas, in which work should be accomplished. These are listed as Group recommendations in Section 9.

3.8 Minimum Control IMC Operation

One of the separation concepts which has been suggested is a system which would theoretically enable equipped aircraft to "see and avoid" all other aircraft under any weather conditions. Such a system sometimes referred to as electronic see and avoid or electronic VFR (EFR) would ideally operate with the following safety characteristics:

1. Safety parameters, at least as good as VFR operations, should be associated with the system, with the likelihood of improvement over actual VFR depending upon the cockpit display and sensor capability.

2. Conflict resolution should require minimum maneuvers which do not disrupt the overall flow of air traffic.

3. Such a system should be compatible with the present and future system where non-equipped aircraft would operate so that any mix of IFR, VFR, and EFR operations would be safe and efficient. The system should also be designed such that no airborne equipment beyond that required for IFR operations would be necessary.

Equipment to accomplish this task under all anticipated circumstances does not now exist. However, there may be certain restricted conditions under which such a concept would function in some airspace with existing or future system design, utilizing ATARS, BCAS, or other contemplated systems. Limitations would include certain requirements for communications with ATC to provide for efficient control of IFR aircraft and for basic conflict resolution. Any E&D development of such a concept should take into account the above listed safety requirements.

4. APPROACH AND LANDING

4.1 Introduction

Fatalities associated with air carrier operations are most commonly related to the approach and landing phase of flight operation. During the period from January 1, 1972, through December 31, 1976, NTSB data shows that 358 out of a total of 585 air carrier fatalities occurred as a result of approach and landing accidents. The next highest number of fatalities in any one phase of flight operation, namely 195, occurred during en route IFR operations.

Approximately 50% of the fatalities occurring in all public air transportation operations, that is air carriers and air taxis, occur in connection with the approach and landing phase of flight. This may be contrasted to 39% of such fatalities occurring en route, and 5% as a result of mid-air collisions.

For operations of small general aviation aircraft, most fatalities actually occur during en route VFR flight - 2,442 out of 3,834 (based upon the same NTSB data used above). The number of fatalities for this segment of the aviation community during approach and landing is 579, however, in terms of accidents, approach and landing is again the most dangerous phase of operation.

It is clear from these data, as well as studies performed by the NTSB and the FAA, that the greatest opportunities for improving safety pertain to the approach and landing phase of aircraft operations.

There are many factors affecting the safety of aviation in this critical operating phase. Some of these relate to equipment availability, procedures, and maintenance, much of which is not basically an E&D issue. However, there are several areas in which current E&D programs can impact the safety of approach and landing operations and in some cases new E&D initiatives are required.

4.2 Landing Aids

Review of safety problems associated with various aids for approach and landing reveals two categories of actions required at this time. The first is simply an accelerated schedule of equipment installation. There are several types of electronic approach guidance, visual approach slope indicating systems, and lighting systems which have been developed and in most cases thoroughly proven. Further E&D, in this instance, is not required and, in fact, could create unnecessary delays in implementation. It is obvious that substantial safety gains can be achieved simply by accelerating the installation of additional proven systems.

Though not an E&D issue, accelerated implementation of this type would complement E&D work and must be given a high priority.

It is of great importance that appropriate steps be taken to ensure and enhance the proficiency of pilots during this more demanding phase of flight operation. The effects of added or improved approach guidance must be analyzed in conjunction with an examination of human performance limitations which constitute a critical aspect of the entire approach and landing problem. The human factor issue is treated in this chapter in a subsequent part of this section, as well as in Section 7.

In the category of specific E&D work which is still required, several important issues have been identified. The first, the subject of system costs, affects all aviation users, but impacts small general aviation operations more heavily than other types of flight operations.

With over 10,000 airports nationwide in use by a very broad spectrum of general aviation aircraft, a need exists for a family of landing aids with a range of capabilities and costs, which will be compatible with the various requirements and financial constraints of the aviation community. Here, as in many of the E&D programs, the cost/benefit considerations must be an integral part of the development planning.

In many instances of general aviation need, landing aids are not available at certain locations basically because the costs of present day approved systems simply cannot be justified for the level or type of aviation activity at that location. As an example, VASI systems of designs most commonly used in the United States can range from multiple box light configurations with up to 16 elements, costing well over $50,000 per system, to simple three element reflective surfaces which are minor expense items for airport operators. Typical VASI systems, which are being installed today, cost approximately $35,000, an amount clearly prohibitive to the small airport operator, even with shared funding.

A very low cost system is clearly limited in its capability, however, it can contribute to safer operations. Careful consideration must be given to developing ideas and systems which can achieve even small increments of safety if the alternative is not financially viable.

With respect to the visual glide slope devices in use or proposed, there is a need for further FAA R&D. In order to make the cost/benefit trade-off implied above, a more precise understanding of the relative merits of each type of system is needed. Discussion with FAA ARD personnel indicates that examination of alternative approach aids is underway. However, the considerations of low-cost are not explicit enough in the objectives of the work, and progress in the effort is not yet satisfactory.

The Topic Group specifically considered and rejected the notion that in-eased deployment of landing aids might have an adverse affect on safety.

2.1 Lighting Systems

The present E&D program does not adequately address questions related to irport lighting systems. Restricted or reduced visibility conditions which cause istortion of approach and runway lighting information must be more systemtically examined so that decisions on new or modified lighting configurations can e based on a more complete and scientific criteria.

The information content of each light configuration can be distinctly lifferent and variable, particularly under non-uniform or varying visibility conlitions. A determination of which system or set of systems is appropriate requires a better understanding of how pilots respond to and use the information supplied by various elements and configurations of light systems.

Changes to light systems should account for many factors with each based upon as much engineering and research data as possible. Such factors should include:

1. Types of aircraft operation.
2. Weather and associated minimums.
3. Energy consumption.
4. Configuration standardization.
5. Installation and maintenance costs.
6. Reliability and monitoring.

4.2.2 FAME

The concept of color-coded lights, within the approach light system which are designed to provide vertical information, is a potentially valuable contribution to approach and landing safety. The mechanization of this concept with Final Approach Monitoring Equipment (FAME) does not require any airborne equipment beyond a Mode A transponder. Because of this lack of any requirement for avionics, the FAME offers an attractive possibility for landing guidance.

There is one aspect of the FAME development which must be examined further. The value of FAME over and above a VASI system is based upon the location of light segments along the final approach path, which would theoretically permit guidance information under restricted visibility conditions when VASI lights would not be useful. Flight evaluations are needed to determine what specific guidance information can be obtained by pilots as a function of various visibility conditions and to determine that the human factors of the proposed light placement do not result in erroneous responses by the pilot.

4.2.3 ATCRBS Instrument Landing Aid

During the development of the Synchro-DABS, an instrument landing aid (ILA) system based upon the ATCRBS transponder was designed and tested. The system is capable of providing localizer and glide slope information at a relatively low cost for both ground and airborne equipment. The ATCRBS ILA would primarily serve the needs of general aviation at small community locations.

Although the system is relatively low cost (approximately $500 for additional airborne equipment) the requirements for the user are in addition to any equipment required for other instrument landing systems now in use, or contemplated. An operator must purchase one receiver to use the ILS system and another different piece of avionics equipment to use the MLS system. Hence, with installation of ATCRBS ILAs, a certain reasonably large class of users would be required to equip with three different types of landing system avionics for a long time into the future.

Because of this added burden of airborne equipment cost, the ILA is not an attractive concept to any segment of the user community and no further E&D resources should be expended for development.

4.2.4 Microwave Landing Systems

Electronic approach and landing guidance system development has been one of the largest elements in the FAA E&D program for several years primarily because of the MLS development. The MLS development and format standardization efforts are responsive to the needs for future instrument landing system capability. In this instance, as in many others, there is a need for a range of capability to adequately serve the needs of the total aviation community. This requirement has been recognized as evidenced by the family of MLS capability under development. It will continue to be important to recognize needs for low cost capability and to adequately manage the problems of transition to MLS.

There will be a relatively long period of time during which many aircraft will necessarily be equipped with both MLS and ILS receiver capability. FAA should support any industry efforts to minimize the cost of having such dual airborne capability since more widespread precision landing guidance availability will enhance safety.

One of the potentials of the MLS concept is guidance throughout a variety of complex segmented or curved approach paths, many similar to those used today under VMC. This concept differs from the ILS procedures in use today which are based upon a relatively long segment of stable and straight flight path prior to landings. As there is substantial evidence to indicate that such a stabilized

operation has contributed to the safety of ILS approaches in IMC, there is a need for further investigation of means to achieve stability during complex MLS procedures before they are implemented in IMC. It should be noted, however, that introduction of precision guidance has a substantial potential to improve safety on certain approaches which have curved segments in present day operations, and are currently conducted using non-precision guidance (e.g., JFK VOR 13L/R).

In order to assure that safety is maintained or increased with the introduction of MLS, additional E&D is required which will focus on:

1. Ways to accelerate demonstration of small community versions of the MLS standard.

2. Instrumentation needed by a pilot to fly complex approach path, manually or automatically and the limitations of pilots using these displays. This should include an assessment of the instrumentation necessary to ensure that the ability of the crew to detect and appropriately respond to wind shear encounters is not derogated during complex/curved approaches.

3. The full range of MLS applications, including missed approaches demonstrated in wide body aircraft using present day automatic flight control systems. The demonstration should also include recent versions of smaller aircraft.

4. The reduction of various signal interferences which MLS is expected to provide over ILS, such as those caused by overflights. These should be fully verified by flight tests in operational environments using manual flight and automatic landing systems.

5. Assessment of ATC operational considerations of surveillance and sequencing of complex approaches, both in simulated and real ATC environments.

6. Development of standards for use of MLS systems of the kind contained in TERPS.

4.3 Coupled Approaches and Automatic Landings

There is ample evidence to indicate that safety will be increased if autopilot coupled approaches are used more extensively including the practice of leaving the autopilot engaged to minimum authorized altitudes whenever possible. Studies performed by NASA, even though they are based on measuring the center of a pilot's view and do not account for peripheral vision, suggest that a pilot will perform a more comprehensive instrument scan when monitoring a coupled

approach than when manually operating the aircraft. One of the major contributors to problems during the approach occurs when a pilot begins to concentrate on outside visual information at the expense of instrumentation data. If the outside information is incomplete or misleading, difficulties arise which would not occur in the case of a fully coupled operation or if the pilot had accurate and complete information available to him.

However, there are several operational factors today which preclude more extensive use of coupled approaches. These factors include a requirement for nonprecision approaches, as well as typical ATC operations, particularly at high density airports, which create situations which are not compatible with the operating limits of the autopilot systems or the workload of the flight crew. Such typical problems include:

1. Higher than normal final approach speeds.

2. Close in turn to the final approach course.

3. Large intercept angles relative to the final approach course.

4. Lateral excursions from the final course once established.

5. Change of landing runway late into the landing process.

6. ILS signal anomalies.

7. Interference caused by intrusion of aircraft or ground vehicles into the areas critical to ILS signals.

8. Concerns by some pilots about the validity of the procedure used to certify autopilot minimum altitudes.

A sample of airline pilot reports which indicates current problems associated with the coupled approach can be found in Appendix C.

The pilot confidence in autopilot coupled approaches has been limited by the every day difficulties encountered in relatively good weather. This can and does have an impact on the use of the systems under more difficult weather conditions even though performance is generally improved by protection of ground areas which cause signal interference and more stabilized approaches.

On the other hand, the capacity of a high density airport is also affected by these procedures, and delay costs might be severe if the same procedures were to be followed under all weather conditions.

E&D is required to minimize the factors listed above without substantial penalty in traffic capacity. The MLS has been shown to have superior attributes with regard to the factors numbered 6 and 7 above and also, in conjunction with improved avionics, the problems summarized by items 1 through 4 above can be significantly reduced with MLS. The potential for increased safety by utilizing coupled approaches is substantial and should not be overlooked even though present ATC requirements often preclude usage.

There are, of course, a large majority of runways and aircraft which are not equipped for coupled approaches. This situation is likely to persist for many years; however, the growth in capability can be accelerated, if the cost of needed equipment is reduced.

E&D is required in order to assess the potential of improved means for the human pilot to monitor the automatic system and what operational limitations are proper for these systems. The net result may lead to achievement of the benefit inherent in more automated approaches, but with the possibility of lower costs, and therefore more widespread availability.

As additional use of fully automatic approaches and landings (autoland) takes place in certain types of operations, there will be questions concerning the proficiency of individual pilots to perform safely these tasks using manual techniques. The FAA E&D program should include research which will assist operators in establishing proper policies and procedures to assess pilot capability in a future, more highly automated landing environment.

4.4 Pilot Decision Making

Many of the approach and landing accidents in all types of aircraft have been attributed to errors in decision making by the pilot. The often complex decision to continue an approach or, alternatively, to initiate a missed approach, is a critical example. In many cases the circumstances have been judged as "indecision" rather than as an "incorrect decision". In all of these instances, it has been difficult for investigators to evaluate the total information actually available to the pilot and to examine the decision process which led up to the difficulty. For aircraft with more than one crew member, the interactions of the crew is also not easily assessed.

Whether the evidence points to visual illusions, inadequate training and knowledge, unusual weather, missed communications or insufficient instrumentation, the critical element relates to some form of human limitation. In order to systematically develop new procedures and improve training, further research is required to answer questions such as, but not limited to, the following:*

*Air Transport Association (ATA) has expressed a minority view with regard to this issue which can be found at the end of Volume I.

1. What visual data are most critical to decision for landing?

2. In what ways can pilot misinterpret incomplete or distorted visual data?

3. What are the factors which make up the decision processes and how can these best be accounted for in training program development?

4. What critical times and dynamic limitations are associated with the transition from automatic approaches to manual operation?

5. What are the problems with the expectations of pilots created by many routine experiences which subsequently influence the decision process during unexpected events? Included in such an investigation would be the psychological effects of desiring to avoid a complex missed approach procedure.

In the development of these programs and the associated capability to simulate various visibility problems during approach and landing, the impact of approach aids such as Head Up Displays, FAME, and VASIs should be assessed. Separate evaluations of approach aid systems is also a part of the present E&D program and should continue. It will be important to integrate those studies with the other human factor investigations to ensure that safety is improved and the cost/benefit considerations are based on the best available data.

The end product of E&D related to the flight crew decision process during approach and landing should be an improved basis for understanding the human role which could be used for developing and certifying systems and procedures. Some additional examples of needs as viewed by one user group can be found in Appendix C.

4.5 Weather

During the approach and landing phase of operation, the possible impact of severe weather becomes very critical. Weather information must be more precise, the location of hazards carefully measured and reliably predicted, and the information expeditiously communicated.

Much of the weather phenomena dangerous to aircraft during the approach is rapidly changing and not easily detected by the systems which monitor large geographical areas nor by reliance only on pilot reports. Investigation should be made to define a weather measurement capability, including Doppler radar, at terminal areas which may give timely and accurate warnings.

Because of the need for minimum delay between detection of severe weather and pilot knowledge of that critical information, special communication procedures

must be developed. Use of DABS data link for such purposes holds substantial promise, however, there are many unanswered questions concerning the format and medium which best provides the cockpit with meaningful information.

For aircraft not equipped with DABS data link, computer generated voice might be utilized. In such instances, voice interference, dedicated channels, data format, etc., are all factors which must be more carefully examined.

E&D is vital in this area if suggested solutions to severe weather on approach are to be practical. Care must also be exercised to consider all classes of users, operating with various levels of equipment sophistication. Solution must take into account the cost vs. availability tradeoff.

Wind shear represents a particularly acute and often deceptive example of weather hazard during approach and landing. The wind shear associated with weather systems, such as thunderstorms and frontal movements, tends to be more of a problem for large aircraft because of the relatively slower response to flight control and power changes.

There is also another form of wind shear created by surface contours and structures which affects smaller aircraft and in fact, has been cited as a cause of several general aviation accidents. During the years 1975 and 1976, the NTSB data shows a total of 19 accidents known to involve wind shear. Of this total, only two were air carriers and 17 were general aviation. Of that 17, thirteen occurred during the approach and landing phase of operation.

A lack of timely information concerning weather which will be encountered by the approaching aircraft is clearly responsible for much of the wind shear hazard, however, there is an additional need. During an encounter with rapidly changing wind velocity, the pilot must have adequate real-time information with which to manage the aircraft trajectory and power setting. The typical instrumentation in today's aircraft is not adequate.

E&D programs are exploring airborne concepts and devices to aid pilot recognition of and response to wind shear. Such efforts are very important and must be continued. The work must be pursued beyond the point of concept evaluation. However, it must also examine the potential value of any system to all types of users with proper recognition of cost. Finally, it must integrate the results of these studies with E&D work on training methods to ensure a comprehensive approach to wind shear problems.

5. WEATHER

5.1 Introduction

The National Transportation Safety Board continues to cite weather as a causal factor in a majority of general aviation acciden*s and as a contributing factor in a significant portion of air carrier accidents. In many cases, pilot knowledge of the weather hazard was incomplete and, in some general aviation instances, non-existent. This lack of information is associated with pre-flight planning, as well as in-flight operation.

In the case of many accidents, there is serious question as to the ability of the pilot to properly assess weather data and translate this information into potential hazards to his particular flight. This specific problem is partly an issue of pilot training and proficiency and will be treated in more detail in another section of this chapter.

The lack of sufficient and timely weather information is caused both by inadequate data gathering capability, and also an often ineffective dissemination capability. The lack of adequate in-flight weather communications between the pilot and appropriate ground facilities is a serious problem for all aviation users. In addition, many general aviation users are victims of insufficient weather data for flight planning. This pre-flight situation is different for some organizations which have developed their own, often extensive, weather information systems for flight planning purposes.

5.2 Weather Information

The National Weather Service (NWS) has the authority and responsibility to observe, collect and disseminate weather data for the general public and for specialized users, such as aviation. Because of the responsibility of the FAA for safety in the National Airspace System, the pilots of all aircraft are in communication with Air Traffic and Flight Service Station personnel in a much more systematic manner than they are with NWS, both prior to and during a flight. Therefore, the responsibility of NWS to disseminate weather data to aviation users necessitates a close working relationship with the FAA. This relationship also extends into areas of weather measurement and observation, as well as research.

5.2.1 Radar

Of prime importance to the NWS weather observation capability is a network of radars composed of 51 WSR-57 systems, 5 WSR-74S systems, 61 WSR-74C

systems, and a WSR-100-5. In addition, some weather information is obtained from FAA en route surveillance radar (ARSR) and airport surveillance radar (ASR).

The WSR-57 is a pencil beam, S-band system capable of vertical and horizontal sweep which allows a storm to be analyzed in three dimensions. It can measure relative echo intensities and cloud tops to approximately 125 nautical miles, with the quality of information deteriorating with range. It cannot, however, provide direct information with respect to turbulence. The system design is based upon detection of precipitation intensities, and turbulence data can only be inferred from that measurement. The correlation between the intensity of the turbulence and the level of precipitation has been found to be approximately 30%.*

Research programs have indicated that using Doppler techniques may enhance the radar derived weather information by directly measuring air movements. This may potentially increase the capability to detect turbulence and, in particular, certain kinds of wind shear which do not contain significant amounts of precipitation. The use of Doppler techniques in conjunction with an improved NWS radar network may enhance the total aviation weather system and therefore an E&D program to investigate this, as well as other means of detecting regions of significant turbulence, is encouraged.

As this combined capability system develops, it would also be important to expand the weather system coverage. The present FAA en route surveillance radar (ARSR) which is necessary to supplement the weather data obtained by NWS radar coverage, is not designed for weather sensing and it is inappropriate to depend upon this system to supplement the NWS network. The L-band frequency and broad vertical beam characteristics of the ARSR, together with circular polarization, fundamentally conflict with requirements for weather detection and measurement. Although the ASR system is S-band, giving better precipitation sensing performance, it also suffers from similar design characteristics which provide for good aircraft surveillance at the expense of weather detection.

Future E&D activity should be directed to determining the best future ground weather radar sensor systems to be employed to resolve the need for basic weather information for pilots. Such systems should provide severe storm information which basically complements that information derived by airborne weather radars eliminating the frequent arbitrary judgments which often occur now regarding the best weather avoidance flight path. The E&D activity should recognize that the aircraft system has the superior position of vantage for weather surveillance, but lacks power, aperture, and processing sophistication to provide long range weather information. Thus, the continuity and netting available from a properly configured ground network radar system used in conjunction with airborne weather radars for weather circumnavigation can provide major improvements in safety and delay reduction. Statistics show that weather related accidents have resulted when the

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*"Application of Doppler Weather Radar to Turbulence Measurements Which Affect Aircraft", J. T. Lee, FAA Report RD-77-145.

airborne radar is used to penetrate extended severe weather activity which a properly configured ground sensor network would sense and could assist the pilot in strategically planning his flight to avoid potentially dangerous weather.

There is serious concern within the user community over the possibility that a new NWS radar system will not meet the specific needs of aviation. The FAA must ensure that any needs other than aviation for which a weather radar will be used, do not result in compromised performance with respect to serving the aviation users.

Development of the weather radar must include the following considerations:

1. Update rates and currency of weather information must meet aviation needs. (An update rate of once every 5 minutes or a measurement of cloud types every half hour may not serve all requirements for aviation users.)

2. An examination must be made of the turbulence information available through the use of Doppler techniques and techniques which measure precipitation gradients. (A combined capability may be necessary.)

3. Flight test data must be obtained to verify the correlation between detection of turbulence as described in 2 and its presence.

4. The performance specification of the NWS system should be reviewed with the aviation users during the development process. The users are specifically concerned with the potential costs and geographical coverage of weather information for aviation use.

FAA has identified a number of programs* to upgrade its capability to detect dangerous weather using improved FAA ground radar systems.

The referenced FAA E&D document describes an FAA E&D program which would utilize a separate pencil beam antenna, mounted on a separate pedestal, which would use the standby ASR-8 radar transmitter and the standby receiver for weather detection and display purposes. While recognizing that such an approach might produce a lower total cost than having separate radars, located at airports and specifically designed for weather detection, the engineering tradeoffs may be severe at certain airports since equipment redundancy would be lost for the weather function and performance might be compromised for both ATC and weather functions. Also, there will be a notch in weather coverage using this technique, caused by the location of the weather radar below the primary radar and its support structure. This may be unacceptable at some locations. Evidently the FAA has some evidence to indicate that electronic interference between the two systems can be minimized. Therefore, before FAA makes a decision to proceed

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*"Aviation Weather System Preliminary Program Plan", Federal Aviation Administration, February 1978.

with utilizing the standby components of ASR-8 and new ASR radars, the E&D should be completed. The implementation program should be designed to permit either a separate stand alone weather radar to be purchased (such as an adaptation of the NWS radar) or the dual purpose ASR approach to be utilized, depending on the results of the E&D.

Several military services advocate an E&D program for improving the weather surveillance capability of its equivalent to the FAA ASR radars in which the antenna system of the surveillance radar is modified to divide the vertical coverage of the fan beam into a number of segments. This is accomplished on the receive side only, which permits feeding several receive channels with information that should be far superior to the present FAA ASR radar fan beam data since a good amount of altitude information would be inherent in the data gathered. This approach, called Constant Altitude PPI (CAPPI), avoids the problem that the stand alone separate pencil beam antenna generates, that of physical interference between the two radar systems which must be close together to make use of the ASR standby transmitter/receiver elements. It is believed that the concept should be investigated by FAA as a part of its program for improving weather surveillance for supporting ATC services.

Airborne weather radar has undergone several technical improvements recently and has become economically feasible for a wide range of operations, including those with single engine aircraft. The basic system design is also one based upon backscatter from precipitation and contouring of signal intensity. Since the safety concerns of aviation are also directly related to turbulence, there is incentive to explore possibilities for Doppler sensing also in airborne systems.

The technical risks associated with this type of development appear high at this point in time, however, there is sufficient payoff and promise to warrant continuing support for such a program.

5.2.2 Automatic Observation

The lack of surface weather observations at many airports is of great concern from a safety standpoint, as well as one of air transportation efficiency. The general aviation community is particularly affected by the lack of current information about the weather at many airport locations. Of the approximately 1,800 airports, which have approved instrument approaches, slightly over 1,000 have no weather observation service.

The cost of establishing manned observation facilities at these locations, as well as several others which support significant general aviation activity, would be prohibitive. Even the use of personnel from other sources, such as fixed based operators, does not appear to be a satisfactory solution. The solution must be one of automation.

An automated weather observation system should be capable of measuring and reporting several parameters. The following five quantities can be obtained quite readily and in a cost-effective manner today.

1. Height of clouds at or below 5,000 feet
2. Visibility or visual range
3. Wind direction and speed
4. Temperature
5. Altimeter setting

E&D should be directed toward, making the following additional quantities available on a cost-effective basis, as soon as practical:

1. Dew point
2. Precipitation
3. Wind gusts
4. Prevailing cloud height
5. Obstructions to vision

For many general aviation uses surface weather information may not necessarily require the same high degree of precision as that associated with air carrier operations. For example, at locations which presently have no cloud information, cloud height data would be very useful to a pilot if a measurement of ceiling is not available or would be too costly.

The FAA has several programs underway to develop an automated system. The Automated Low-Cost Weather Observation System (ALWOS) is designed to fulfill the requirements at most of the general aviation locations cited above. Low cost and low maintenance characteristics of such a system are essential to its success. Development and installation of these systems, along with appropriate communications capability to disseminate the basic data, is the most important E&D safety program for the general aviation user.

Although the FAA Weather Plan provides nicely for an increased number of more accurate observations which, when combined with more functional procedures to collect, collate, and distribute pilot reports (PIREPS) for more and better

weather information, it does so as a part of the overall ATC system. That is, for pilots who fly in such a way as to have regular communications with an FSS or ATC facility, the plan seems to be comprehensive, however, it ignores the vast majority of pilots who normally have very limited, if any, contact with FAA facilities. The procedures outlined in the plan revolve around the current FAA philosophy of a one-on-one, controller-to-pilot communications network. This one-on-one format is incapable of providing pilots with needed weather information. Witness the growth of the numbers of Air Traffic Service personnel dedicated to current ATC procedures. Clearly, budgetary constraints do not permit this type of procedure to continue and/or grow in the weather information arena. It is also just as clear that the procedures outlined in the plan do not permit service to those pilots who are not part of the system. If all pilots were to become part of the ATC system, the plan's methodology would be useless. One possible E&D initiative to address this issue is development of better techniques for widespread weather information broadcasts.

5.2.3 In-Flight Data Gathering

Because of today's extensive operation of aircraft over a wide range of altitudes, the real-time airborne measurement of atmospheric data represents a substantial aviation weather resource. Data obtained from airborne aircraft can be an important contribution to weather forecasting and real-time reporting for any location.

The utilization of this resource may be based upon pilot reports, as well as automatic sensing systems. PIREPS have long been a source of special weather data and specific weather warnings. In general, however, the potential value of PIREPS has not been realized. There is no systematic method for soliciting, compiling or disseminating such information. Also, the content of PIREPS is not integrated into the weather data base to be used for forecasting purposes, but is only retransmitted in the initial format. Even this limited procedure is not adequately accomplished, in that many PIREPS are not utilized at all because of ATC personnel workload. There is evidence to indicate more than half of today's PIREPS are never used. These reports should be used for more effective forecasting and reporting winds aloft, cloud tops, icing conditions, and other weather affecting the safety of aircraft operations. The role of the ATC controller is critical to the proper functioning of such a pilot reporting system and will be discussed further below.

Because of the demands on controllers and flight crews, comprehensive weather information measurements and timely transmission is not always feasible. In order to better utilize this substantial data source, an automatic airborne weather sensing system should be developed. A selected sample of general aviation and air carrier aircraft, which can measure weather phenomena and transmit these

via a data link, such as that associated with DABS to an automated ground system, would provide a current base for more accurate forecasts, as well as information to controllers and pilots. In addition to supporting the basic aviation weather system, the automatic airborne weather measurements will allow air carrier and many general aviation operators to optimize flight plans with regard to fuel consumption and passenger comfort. It will also assist in the provision of real-time accurate forecasting of weather hazards. An E&D program should be established to design such a program, including not only development of sensing devices, but also an analysis of how to select the aircraft sample and process the transmitted data.

The complete integration of any automatically obtained airborne data, as well as PIREPS, into the total aviation weather data base is fundamental to improving the basic forecasting capability. It is not sufficient merely to develop better methods for transmitting PIREPS and other airborne data between ATC facilities or between the ground and the cockpit. This represents one of the largest deficiencies in the present FAA E&D planning.

5.3 Communications

The gathering of weather data and development of forecasts will not serve the interests of aviation safety until and unless a system is developed which facilitates the transfer of that information to the appropriate people with minimum time delay and in a format which satisfies the needs of the receiver. For example, air carriers find difficulty in using certain terminal forecasts which contain extensive use of variable parameters, or are not sufficiently current. Winds aloft forecasts are often up to 12 hours old, creating flight planning difficulties. Shorter term forecasting is necessary for all user types.

The FAA weather program plan has recognized many of these deficiencies in the present system. Carrying out the necessary E&D programs to solve these problems must be accomplished without any undue delay.

5.3.1 The Role of ATC

The addition of Conflict Alert and Minimum Safe Altitude Warning (MSAW) to the Air Traffic Control (ATC) system has emphasized the importance of the ATC controller's participation in aircraft and terrain collision avoidance. The user community believes that the avoidance of weather which affects the safety of flight is a common hazardous event and commands the same priority of attention as aircraft and terrain collision avoidance. To obtain a hazardous weather avoidance capability, it will be necessary to provide ATC controllers with real-time weather data from both ground and airborne observation sources to blend with the trend data available from the forecasters. Blending the real time availability of data on weather that affects the safety of flight with an effective communi-

cation link between the ground and the cockpit to permit information transfer and timely weather avoidance actions will greatly enhance air safety.

There are several concepts under development which provide real-time weather data resources in the principal ATC facilities. Through the use of better communication facilities, as well as weather experts physically located in proximity to controllers, the ground based side of the ATC communications link will be greatly enhanced. The user community supports the present FAA planning in that regard. To complete that communications circuit, an effective link between the ground and the cockpit must be assured.

There are several human factors and operational aspects of the weather communications between controller and cockpit which must be properly considered.

1. Priorities of controller responsibility for traffic separation and terrain avoidance vis-a-vis weather.

2. Means for effectively delivering weather data which minimizes cockpit workload.

3. Development of a weather data format which is most useful to pilots.

4. Consideration of appropriate controller interfaces with general aviation operators not equipped with airborne weather equipment.

5. Methods for integrating weather information with other required data on the air traffic controller's display.

Most of the weather information used by the general aviation pilot for flight planning, and a significant portion of that used to update in-flight knowledge, is communicated through the FAA Flight Service Stations. The demand for such communication clearly outstrips the capability of FSS personnel. The need for automation in this area is clear and has been recognized for some time. Although considerable E&D effort has been accomplished on this critical safety issue, implementation of systems has been slow. Again, consideration should be given to the safety implications of delay for the sake of added sophistication or precision.

5.3.2 Time Critical Information Transfer

Weather hazardous to aviation operations is sometimes quickly moving and isolated. It, therefore, is critical to have accurate real-time sensing systems which make prediction of such hazards readily available. Assuming that the basic capability to measure and/or forecast weather affecting aircraft safety of this type has been fully developed, the transfer of such information to the aircraft in a

manner and form which is meaningful to the crew becomes a paramount issue. The strategy to avoid a hazardous condition must be developed cooperatively between controller and pilot. Decisions such as holding, rerouting, or alternate runway selection might be included in that strategy. Transmission of such communications, and a decision process dependent upon voice communications, might contribute to significant delay and possibly impact safety.

The use of data link for such communications would serve to alleviate such a problem. In addition, the ATC computer in conjunction with data link can provide automatic ATC strategic planning to account for weather problems. Critical data, such as that associated with wind shear, must be transferred to the cockpit as quickly as possible.

There are several parameters, such as aircraft ground speed (based upon improved surveillance data), surface wind, and others, which might enhance the ability of an airborne detector and/or display systems to provide timely information to pilots. An analysis should be made of what types of data, transmitted via data link, would be most useful to aircraft encountering wind shear problems.

Similarly, data linked airborne information should be used by a ground system to update wind shear prediction, particularly on approach paths. This information can be used to automatically develop a plan for managing the approach and departure ATC operations, as well as for providing current weather data for subsequent aircraft approaches along similar flight paths.

The optimum use of all available weather data and the decision process, both airborne and in the ATC facility, requires additional E&D effort.

In all of the safety issues related to weather information needed in the cockpit, and in particular for those instances where time delays must be avoided, the FAA concept that ATC controllers assist, if time permits, must be carefully reexamined. The requirements for safe operation cannot disregard one hazard in order to optimize another. All safety issues must be addressed concurrently.

6. WAKE VORTICES

6.1 Introduction

Wake vortex effects, like those of wind shear, are not new to aviation, but a better understanding of this phenomenon and a more accurate measurement has helped to focus needed attention on this potential safety problem. Regardless of the size of an aircraft there are circumstances under which serious hazards exist if that aircraft is in close proximity to another which is generating a turbulent wake. Solutions should be sought which address the generation of wake vortices, as well as the avoidance of those that present a hazard.

6.2 Wake Vortex Avoidance

Considerable work has been accomplished which measures aircraft vortices and defines vortex intensities generated by particular types of aircraft, as well as the relationships between the decay and movement of vortices and atmospheric conditions. The FAA development objective of the Wake Vortex Avoidance System (WVAS) has been to establish criteria for minimum separation which depend upon a prediction of vortex behavior. Under certain wind conditions, reduced longitudinal spacing can be used with substantial increases in capacity. However, there remains a substantial operational efficiency penalty when such spacing cannot be safely used.

In addition, there are safety concerns for wake encounters in situations other than closely spaced approaches. The strength of most large aircraft vortices is greater in a clean aircraft configuration because of the concentrated reinforcement of the vortices at the wing tips, rather than vortices established at several locations due to flap and gear extension. In a departure situation, following a B-747, a time interval of up to 2 minutes may be required to ensure safety with respect to the wake. This translates into 7 or 8 miles of separation. Although encounters of this type will most often occur at higher altitudes with the attendant extra margin of safety associated with the added altitude and airspeed, the effect on aircraft may still be a serious safety problem and certainly can be an unacceptable situation for passenger operations. No practical measurement or avoidance systems are yet available for these cases.

Development of ATC concepts which provide closer aircraft separation, more precise departure and missed approach guidance while at the same time accommodating the present mix of small and very large aircraft must account for possible wake turbulence problems. This consideration must be an integral part of the E&D associated with further ATC systems.

Through the use of MLS, it may be cost-effective to generate multiple glide slope paths which will permit wake vortex avoidance at relatively close aircraft spacing by providing vertical separation of aircraft from vortices. This concept should be further analyzed by FAA E&D.

FAA research has shown that when the Vortex Advisory System is used, 3-mile separation is safe in a very large percentage of cases for any mix of aircraft sizes. These results apply to the approach path from the outer marker in, however, preliminary analytical results have indicated that the same conclusions are valid for higher altitudes. Also, strictly from a vortex standpoint, parallel paths as close as 2,500 feet appear to meet adequate safety standards, however, further test data should be gathered before such a procedure is implemented under IMC conditions. (There are, of course, many other considerations governing safe separation standards in addition to wake vortices. These are discussed elsewhere in this report.)

6.3 Wake Vortex Alleviation

In spite of wake vortex measurement systems, there will be many instances when traffic separation must be increased beyond the 3-mile minimum. The decrease in traffic capacity during those times may be substantial. In addition, there are many pressures to decrease longitudinal spacing to even less than 3 miles. These considerations coupled with possible wake encounters in situations other than final approach provide sufficient motivation for seeking methods to minimize the vortex generation at the source. This clearly should be the ultimate goal.

Studies performed by NASA and FAA have indicated some potential methods for reducing vortices on present day large aircraft by deploying certain spoiler segments. There are several possible configurations, some of which have been through a flight test program, and some of which have insufficient test data to adequately assess the cost-effectiveness. Further, E&D is also needed to assess the impacts on noise, vibration, engine performance, and aircraft response under the various aircraft configurations which may decrease wake generation.

Because of the substantial capacity payoff possible through wake vortex alleviation, E&D must be given high priority. In addition, FAA should encourage NASA and the aircraft manufacturing industry to develop new concepts for wake alleviation, such as wing fences which can be an integral part of a newly designed wing. Such solutions not subject to the normal limitations of a retrofit program may be the most cost-effective.

7. DATA LINK

7.1 Introduction

The use of a data link system to enhance communications between aircraft and between an aircraft and ground facilities can potentially increase the safety capacity and efficiency of the NAS system.

The potential for DABS data link, insofar as safety is concerned, falls into two categories. Safety impacts which will be felt as by-products of systems or procedures designed for capacity and/or productivity increases, primarily because of improved air/ground communications and those potential uses of a DABS data link system which are specifically intended to address safety issues.

7.2 Data Link in Conjunction with ILS, MLS or ATARS

Information relative to the aircraft dynamics, as measured by airborne instrumentation, can potentially be a useful augmentation to certain ground derived data. For example, during the approach and landing phase of operation, airborne MLS information can theoretically be transmitted to a ground monitoring system to enhance the capacity of that surveillance function. The ability to resolve problems during closely spaced parallel approach requires very short detection and warning times which might not be possible without augmented data such as the aircraft bank angle. The need for such data is a function of the spacing standards which are used. Those standards, the capabilities and limitations of surveillance radar and the potential use of data link information must be examined simultaneously.

At this point in time, however, it is the feeling of the user community that no MLS operation should be predicated upon use of an air-to-ground data link system in order to meet reliability or performance criteria. However, for communications purposes, data link should be used to minimize delays. Because of the limited number of aircraft likely to be equipped with a DABS data link capability, as well as the position of the users at this time, with regard to application of an MLS data link concept for enhancing surveillance capability, FAA E&D should not place priority on this issue. All near term planning for MLS and monitoring of MLS operations should be independent of any air-to-ground data link data augmentation capability.

In a similar fashion, airborne measurement of turn rate, descent rate, or other dynamic parameters can provide important information to the ATARS computation of conflicts and conflict resolution. Possible techniques and uses for

such a transfer of data via a DABS data link should be evaluated, however, ATC system design concepts and operational procedures which involve ATARS should, at this time, be based solely on the ATARS performance without such data link usage. If ATARS is to provide a backup capability for aircraft on closely spaced parallel approaches, the possible need for added capability is apparent, as in the case for the MLS. The resolution of this issue is tied to the other questions of separation standards and radar surveillance capability.

Downlinking of air derived guidance data for purposes of enhancing ATARS operations or to permit more closely spaced IFR parallel approaches should not receive E&D attention.

7.3 Weather Information

The lack of real-time accurate weather information in the cockpit is clearly one of the most serious safety issues. A DABS data link can provide a means of furnishing such data to pilots. However, for a long time, a relatively small percentage of the total aircraft fleet will be equipped with a data link capability and therefore resolution of the majority of weather information dissemination problems must also be pursued in other ways.

For those aircraft with a DABS data link there are several concepts related to weather information dissemination that have great potential safety benefits. First, the transmission to ground facilities of airborne weather measurements can benefit all aircraft operations. This concept was discussed in more detail in Section 5.2.3.

Second, real time and comprehensive weather information from ground stations can be made available in the cockpit. Display of such data and the operational use of the information needs further examination. It is critically important to develop a format for weather data which meets the needs of the pilot, particularly in those instances where very little time is available for assessing weather information and making operational decisions.

The needs of the typical general aviation pilot for weather information are often quite different from those of the air carrier pilot. Hence, design of a data format must assure that the final product or products meet the needs of both.

7.4 Other Safety Benefits

The inherent quality of more reliable and faster communications between ground facilities and aircraft characteristic of a data link concept underlies most of the safety impact possible through the use of a DABS data link.

There are several messages of an ATC clearance nature, such as take off or landing clearance, altitude assignments and others, which occasionally create safety problems. A reliable data link capability would help to eliminate such problems. The present FAA E&D programs are addressing these issues and should be supported.

Flight plan filing and ATIS information are also candidates for data link usage. The incorporation of such capability would potentially impact the efficiency, as well as safety of the system. Again FAA has appropriate E&D concentration on these issues.

An overall concern which may not have sufficient E&D emphasis is the cost-effectiveness of the DABS data link system. The applicability of data link concepts to any operation, particularly to small general aviation aircraft, hinges upon the associated costs. If costs are such that a small number of aircraft are equipped, the overall impact on safety will likewise be small. Because of the possibility of limited equippage, any serious safety issues which might be resolved through data link must also be addressed by alternative systems or procedures.

7.5 Human Factors

The most serious safety issue arising out of the development and application of a data link capability is related to human factors.

Many applications of data link are of the nature of a substitute for VHF voice communications. While increased efficiency of the ATC system is possible, as well as reduced opportunity for error through misunderstanding, there is a fundamental loss of certain information present in today's voice broadcast system.

The many ways in which common channel information is used to monitor ATC operations and anticipated instructions is not clearly understood. It is clear that certain safety benefits accrue from this "party line" information and a better understanding of the actual operational environment must be developed before the present voice communications system is replaced by data link. A priority E&D effort should examine that question as soon as possible.

Resolution of those concerns need not and should not delay DABS data link development or implementation. By using voice and data link ATC communications for at least an interim period, the effects of the data link can be assessed and many of the benefits realized without the potential safety reduction associated with a loss of party line voice communications.

There is a broad area of human factors issues related to DABS data link which is common for any new device. The interface between the data link system and the pilot and controller, must be carefully analyzed. Preliminary work has been accomplished* on certain input/output devices for use in the cockpit; however, a much broader study of this problem is required, including the effects of human errors and use of the data link during abnormal operations.

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*"Human Factors Experiments for Data Link", James M. Diehl, Report No.: FAA-RD-75-160.

8. Pilot Training

8.1 Introduction

Because a large percentage of accidents and incidents are related to pilot actions or decisions, it is important to examine any avenues which might provide better insight into this critical element of the aviation safety picture. Questions of new instrumentation, new operating procedures, and basic human factors, with regard to specific operational situations, have already been addressed in this report. However, it is also important to focus specific attention on the possibilities for increasing safety through the use of improved pilot training and more effective techniques for maintaining pilot proficiency.

Improving the entire process of training pilots can play a key role in reducing pilot related accidents. Also, one of the most comprehensive tools for training, namely the use of simulation, is becoming more and more effective and economically attractive. Several E&D safety issues arise when simulators are used for training.

8.2 Training

The complexity, as well as the size of aviation operations has undergone remarkable growth in the last twenty-five years as evidenced by highly sophisticated present day high performance aircraft. In addition, the typical aviation navigation and communications equipment has progressed to a relatively complex level. Coupled with the introduction of new procedures and regulations, these changes demand a comprehensive level of knowledge and skill from the individuals in the cockpit.

The fundamental techniques and processes for student pilot training have addressed additional demands created by changes simply through add-on study programs, requirements and additional checks.

As discussed previously, more and more evidence points to the pilot as the most critical element in the aviation safety story. The most fundamental, and perhaps one of the most cost-effective methods for increasing the safety level of the pilot, is in the student training process. Advances in educational science and teaching aids have been substantial in recent years. Most of these are not being utilized in aviation training programs. The following should be addressed by the E&D process:

1. Develop a study to qualify and identify those new educational processes that consistently produce acceptable performance standards, to be adopted in lieu of numerical minimums. This would avoid unnecessary hardship or delay in the issuance of a pilot certificate or rating to an otherwise qualified individual. The program should be tailored to remain within the existing framework of initial qualifications and renewals. In order to gain industry support and acceptance, any semblance of "add-on" requirements should be avoided.

2. Simulators should play a greater role in meeting initial training, recency of experience and testing requirements.

3. Cost-effectiveness is an essential element in any method developed for these purposes.

The FAA and the NTSB have identified some objectives in conjunction with specific safety problems such as stall/spin training. Training in pilot judgment is another problem area. It is not sufficient, however, to address particular problems one at a time and seek special added training for each. The need for pilots to understand and cope with stall/spin problems, or to exercise good judgment in flying, is obviously essential, but this need must be fulfilled as part of an overall training and proficiency concept.

There are many safety problems in aviation for which procedural or hardware additions and/or changes are developed to compensate for human performance problems. In some of these cases, a more effective training program would provide a broader solution. The development of such a program is an important safety issue and should receive FAA consideration in consultation with the users.

8.3 Flight Simulators

New concepts for pilot training have been motivated by advances in simulation technology and incentives for reducing fuel consumption. The safety benefits inherent in simulation versus actual flight, particularly for training in abnormal emergency procedures are clear.

For the purposes of this discussion, the terms simulation and simulators will be used in a broad sense to mean any device short of an aircraft which can be used for training personnel in aviation. The FAA has developed a minimum set of criteria for which a device can be considered a "simulator." Other devices with lesser capability have been grouped into a category called training devices -- a category not yet fully defined by FAA.

The progression of simulation in aviation clearly points to a continuum of capabilities with devices designed for a wide variety of training purposes and in accordance with the characteristics of a wide variety of aircraft. It is cumbersome and somewhat arbitrary to draw a line above which devices are called "simulators" and below which are something else. FAA can and probably should categorize classes of simulators, but because of the generally accepted terminology of simulation, an arbitrary dividing line between simulators and training devices is not appropriate.

In the development of simulation capability it is essential that designers address specific objectives and purposes. These, in turn, revolve around the requirements of FAA related to certification, currency, flight checks and so forth. At the present time users of simulation devices must propose a program to FAA with an explanation of what is to be accomplished in the simulator, and in each case FAA will make a judgment on that proposal. While the individuality of each user's need dictates such a format in most cases, the judgment of FAA must be guided to the greatest extent practical to eliminate wide variations of requirements from one FAA facility to another and to help reach the standards for simulation that, indeed, achieve the proper training objectives.

There is a considerable need for E&D to provide that guidance. Scientific data is needed to establish a better base from which judgment can be exercised in the assessment of simulation capabilities and decisions. Limited work has been performed by FAA NAFEC which begins to address these issues, however, considerably more research is needed.

One of the most serious problems associated with a lack of data is the likelihood of overspecifying requirements and thus making the entire simulation portion of a training program too costly. Until there is a better understanding of how each parameter of simulation, whether it be motion, visual display or others, contribute to the various skills development of each type of pilot, decisions on the adequacy of any training device will be somewhat arbitrary and probably favor a costly and sophisticated capability with the hope of ensuring safety.

The FAA must allocate E&D resources to answer the following fundamental questions about simulation:

1. What is the importance of motion to the training of various flying maneuvers and for the various skill levels applicable to each segment of aviation?

2. How can visual simulations be classified to relate the information content of the visual scene to the various training objectives? Basic to this question is a better understanding of how pilots utilize visual cues in the

performance of each task. Included in this examination should be questions of simulated visual illusions, disorientations, distortion by precipitation and other real world visual problems.

3. What are the psychological effects of simulator training on the confidence of pilots to perform in the aircraft? The proportion of training in simulators versus aircraft depends upon the levels and purpose of training, as well as this psychological understanding.

4. How can a minimum standard of simulator capability be established for the various levels of basic pilot training which achieves appropriate safety goals in the most cost-effective manner?

There will be continued pressure to use simulation to analyze and resolve issues such as cockpit workload, procedures, encounters with weather hazardous to flight and interfaces with new, more automated systems. Underlying all these pressures will be the obvious safety advantages of simulation over actual flight for training. In every case the credibility of the simulator as a device which truly answers the questions or accomplishes the training objectives is critical.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 General Conclusions

Many of the safety problems identified by Topic Group 4 can be substantially resolved with the installation of already developed equipment, such as various landing aids now available. There is a general feeling of the group members that the schedule for installation of certain of this equipment has not been adequate and should be accelerated, however, the installation of equipment was considered to be outside the scope of responsibilities of Topic Group 4, so no details related to this issue are contained in this chapter.

There are several E&D related conclusions which were reached by the group and which are relatively broad in nature. More specific E&D recommendations are found in the following subsection (9.2).

1. Human performance is clearly the largest general category of safety concern in the operations of all segments of the aviation industry. Actions of the pilot are cited more than any other factor in accidents of all types of aircraft. The FAA E&D progress in this subject area has been inadequate historically. Present E&D planning appears to recognize the relative importance of this issue, however, it is not clear yet whether E&D has truly made the necessary commitment for this critical research. Priority treatment is urged.

2. The most important safety issue relative to general aviation operations is the availability of accurate and timely weather information for the pilot. This same issue is a major concern for all other segments of the aviation user community as well.

3. Allocation of E&D resources must be made in a manner which produces the largest incremental safety gain for the associated resource investment. This cost/benefit consideration must be tailored to each segment of the aviation community. The proper cost/benefit criteria are not constant among the various user groups, but depend upon the acceptable risks and burden of costs associated with each.

4. Increased automation, while offering many potential benefits in areas of efficiency and capacity, and perhaps safety, also introduces a high level of complex interfaces between humans and computers in a real time and often critical environment. There are many safety issues which must be comprehensively addressed prior to implementation of major automation concepts.

5. The development of the future ATC system must include the requirement that the ground element of the ATC system accept a portion of the responsibility for separation of aircraft from weather which may be hazardous to flight.

6. There has been insufficient real-time operational simulation and evaluation of the BCAS and ATARS backup separation assurance concepts. Simulations are required to answer a variety of questions concerning the actual operation and interrelationship of ATARS, BCAS, CDTI and others, as well as detailed examination of various failure modes under realistic operational conditions.

7. The role of primary radar and the plan for development and installation of DABS should be reviewed in light of specific user concerns detailed in this report.

8. Approximately 50% of the fatalities are associated with the approach and landing phase of flight. More E&D effort should be expended in this general area. The problems associated with low visibility have been brought out and should receive more E&D since accident rates in Category I conditions are very high in relation to those associated with VMC.

9.2 E&D Recommendations

The following is a brief summary of the key recommendations for FAA E&D initiatives which have resulted from the deliberations of Topic Group 4. Additional details for each of these can be found in the proceding text:

1. Use of E&D resources on issues related to primary radar should be in accordance with the following:

    a. Fulfilling future aviation weather information requirements should not depend upon present FAA primary en route radar.

    b. E&D programs for ATC en route radar development should recognize the preminence of weather performance and coverage as their objective.

    c. Procedural non-radar separation should be continued as an alternative to beacon-based traffic separation.

    d. Development of en route traffic surveillance capability should emphasize coverage which provides optimum ATCRBS and DABS service.

e. Improvements to the en route beacon-interrogator surveillance system should concentrate on modifications which might provide a more cost-effective surveillance and aircraft separation service. For example, in certain regions higher update rates may be needed.

f. The long range plan to reorient en route primary radar service as set forth above should be reviewed by the aviation user organizations.

g. FAA E&D efforts to develop airport surface traffic surveillance should include both primary (ASDE) and secondary radar techniques. Development of secondary methods should not necessarily depend upon beacon sensors being co-located with primary radar (ASR) antennas.

2. The backup separation assurance system should be based upon the following:

a. The FAA should support the development of active BCAS systems to meet a variety of potential user needs. E&D should specifically examine the system designs to determine if the alarm volumes allow compatible operation for all types of airport operations (including uncontrolled airports).

b. The FAA should continue the development of a DABS/ATARS that is capable of coordination with active BCAS.

c. The FAA should undertake the development of BCAS capability which will provide backup aircraft separation assurance for a full range of traffic environments.

3. The issues related to human interfaces with automated systems require further E&D attention as detailed in the following:

a. Design of input/output devices in the cockpit which minimize pilot interpretation errors and input blunders should be examined. The fundamental human factors concepts associated with such designs should be explored by NASA and industry, as well as FAA, but all should have the support and the guidance of FAA to ensure applicability to the actual aviation environment.

b. The question of appropriate level of direct human involvement in the air traffic separation or navigation function, versus the level

of human monitoring should be given more emphasis. The users were unable to reach specific conclusions or recommendations due to the limited amount of relevant information presently available. The optimum use of human capability and techniques for minimization of opportunities for human error must be better understood.

c. There should be additional real-time simulation and operational evaluation of ATARS and BCAS systems in an operational environment to assess their ability to provide backup against pilot or controller errors.

d. Work must establish the tolerance of the overall system design to human error, and the achievement of system safety under backup separation operations caused by human blunders.

4. The degree to which pilots can or should be involved in the air traffic separation process is an important issue in the development of the future ATC system. The display of traffic information in cockpits which might support increased pilot participation raises many fundamental questions which should receive priority E&D attention. (See Section 3.4.)

5. Substantial E&D resources should be allocated toward development of truly low cost landing aids for general aviation airports.

6. There is general agreement that increased use of coupled approaches or autoland systems can enhance safety. Several operational factors characteristic of today's ATC system, as well as equipment limitations, particularly in older aircraft, preclude use of coupled approaches when they would otherwise be appropriate. An E&D initiative should investigate ways to minimize these constraints to additional use of coupled approaches.

7. E&D should examine the issues of critical weather information availability in the cockpit during the approach. Methods for directly sensing critical weather parameters in the cockpit, as well as for expediting transmission of such data from ground sources should be developed.

8. A network of improved weather radar should be developed, including consideration of techniques such as Doppler, to detect turbulence. Weather information for aviation should not continue to depend primarily upon today's en route or terminal surveillance radar.

9. Any necessary E&D to provide for automatic surface weather observation capability should be expedited.

10. An E&D program should be initiated to automatically gather in-flight weather data which can be automatically integrated into the forecasting and reporting system to provide information to all aviation users.

11. To be truly useful, PIREPS of weather information should be integrated into the weather data base in real time for use in forecasting. The present system of handling PIREPS does not use the information in forecasting and only partially makes PIREP data available to all interested users.

12. A specific E&D program to examine the possible safety impact of lost voice communications associated with certain uses of data link should be identified and given priority consideration.

13. A specific E&D initiative should be identified which will examine the potential safety benefits which can be realized through improved pilot training. (See Section 8.0 for details.)

14. Objective guidelines should be developed which can form the basis for simulation certification and approval. In particular, a more technically sound basis should be established for assessment of visual system feature, motion cues and sound.

15. The DABS sensor in some applications, where higher data rates or special coverages such as airport surface regions, are needed could be based on electronically rather than mechanically scanned antennas. The development of the DABS should consider this possibility in order to assure that the most cost-effective technique is provided.

16. There is a need to demonstrate the suitability of MLS for use in a wide range of applications and to develop proposed safety standards for its use.

APPENDIX A

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NEW ENGINEERING & DEVELOPMENT INITIATIVES -- POLICY AND TECHNOLOGY CHOICES

CHAPTER V

NON- OR LOW-CAPITAL POLICIES TO IMPROVE EFFICIENCY

Topic Group 5

Final Report

I. Introduction

Serious capacity shortfalls will occur at a number of large metropolitan airports through the 1980's and 1990's if recent projections of aircraft movements and airport construction activities are reliable. Specifically, general aviation activity is expected to continue to exhibit the sustained, vigorous growth that it has recently experienced. Concurrently, air carrier movements, even after adjusting for increased load factors and the use of larger aircraft, are also projected to steadily increase (albeit at a more moderate rate than GA movements) through the 1990's. Yet in many metropolitan areas the number of airports is unlikely to increase over the next twenty years; new capacity must be provided by upgrading existing facilities. With few exceptions, rapidly rising land acquisition and construction costs and local political and environmental constraints dictate that demand growth will have to be accommodated within existing airport locations.

The task of formulating effective policies to alleviate or avoid the problems consequent to increases in air traffic demand is neither hypothetical nor postponable; even now several large metropolitan airports have experienced excess demand to the extent that demand restraint policies (quotas at four airports and peak hour landing fees at two airports) have been introduced.

Currently, feasible policy options for controlling the problem of excess demand include the encouragement of new capital investment in more efficient configurations of existing airport facilities, the development of new technology in air traffic control, and the promulgation of non- or low-capital policies directed at increasing efficiency in the use of existing airport facilities.

To some degree effective airport capacity may be enhanced by remodeling existing airport facilities (i.e., lengthening present runways and/or construction of new runways) and by advancements in air traffic control technology. Dependence on these options, however, is unlikely to provide all of the needed capacity. As noted above, in most cases large-scale airport development initiatives are largely foreclosed as planning options because of cost, environmental, and political considerations. Also, according to recent FAA studies, over the next twenty years expansion of airport capacity consequent to the implementation of technological advances will be insufficient to accommodate the projected levels of airport activity with acceptable levels of congestion delays and costs at some airports.

Hence, because there is little possibility of adding adequate physical capacity to some congested airports (or terminal areas) and because the number of movements that may be accomplished at those airports is not likely to increase at a sufficient rate, it is clear that some restraints on aircraft movements at those airports may be required. It has been the responsibility of group five to ascertain the feasibility, effectiveness, and "fairness" of airport planning, financing, and operation policies (ranging from administrative to purely economic in character) designed to mitigate the anticipated shortfall in airport capacity.

Although both new policies and changes in existing policies were considered by the group, there was no attempt to address several important, highly controversial issues relating to the topic under discussion, in recognition that it was necessary to move as quickly as possible to the heart of the problem. First, no attempt was made to provide analytical definitions of airport capacity, congestion, delay, and other concepts. Second, the analysis was conducted with an assumption that the technical evolution of air traffic control would exclude airspace congestion from

being a significant constraint in the problem under discussion. Third, it was resolved that the policies considered would be applicable only to those airports (on the order of twenty in number) which are expected to experience capacity shortfalls by 1995.

The topic of prime concern to the group was the development of policies to enhance the ability of airports to accommodate increased aircraft movements. The capability of the system to accommodate aircraft movements is known to be related to the temporal and spatial patterns of those movements. Aircraft movements exhibit a definite pattern over the hours of the day, with pronounced peaks in the morning and late afternoon hours. One the one hand, the existing temporal peaks reflect air travelers' preferences in arrival and departure times and air carrier scheduling practices; on the other, they exert a pronounced constraint on the daily (or annual) capacity of the system. It has frequently been observed that significantly higher levels of daily movements could be accommodated by an airport if their hourly distribution were more uniform.

The spatial pattern of air traffic may cause "spatial peaks" of demand at busy airports and thus also constrain the effective capacity of the airport/airway system. Illustrative of this, at a moment in time a large proportion of the air travelers passing through certain of the "hub" metropolitan airports (i.e., Atlanta and Chicago O'Hare) are connecting to other flights and have no intrinsic desire to visit that particular city or airport. Further, the tendency of air carriers to concentrate schedules into a congested airport (e.g., O'Hare, San Francisco Int'l) while slack capacity exists at others (Oakland, Chicago Midway) limits the effective use of the airport capacity in a region.

While one of the primary tasks facing group five was the development and assessment of policies designed to modify patterns of demand for airport

movements, it was recognized in the initial meetings that several of the factors contributing to temporal and spatial peaking were inextricably interconnected with issues that would extend beyond the original "charter" of the group. As an example, spatial peaking could be aggravated by net reductions in the number of small airports within metropolitan regions. It was hypothesized that the closure of small airports tended to exacerbate existing supply/demand imbalances at the metropolitan airports, for many GA operators (particularly those in transit) are forced to use the busier facilities -- facilities which, on balance, many would prefer not to use. Another factor which was seen to adversely affect temporal and spatial peaking and, therefore, effective capacity, was the promulgation of ever more stringent environmental regulations. These and similar policy issues relating to the enhancement of effective capacity are discussed in Section II of this report; Section III presents the description and analysis of policies specifically designed to modify the demand for airport movements.

Finally, it should be observed that while the "charter" of group five was to evaluate "non- or low-capital policies" which might alleviate the projected capacity shortfalls, the group was particularly concerned that its deliberations within that format not be misconstrued as acquiescence or approval of any reduction of FAA efforts to expand airport physical capacity through expansion, new construction, or other means such as the utilization of military and ex-military airfields.

II. Recommendations to Enhance Effective Capacity

Although it was not the primary concern of group five to provide a detailed assessment of measures designed to expand the physical capacity of existing airport facilities, the group did identify five physical capacity policy options requiring little or no capital investment which could alleviate the projected capacity shortfall in some degree. Recognizing that many of these areas of concern might be discussed more completely by group two, the group nonetheless throught their importance warranted brief recognition in this report.

1. The addition/designation of GA/Air-Taxi runways. Insofar as the potential is not yet exploited, funding policies encouraging the contruction of non-interfering, low-capital runways capable of supporting GA/Air-taxi traffic may significantly enhance the capacity of some busy metropolitan airports. In other instances additional capacity benefits may result from the simple expedient of designating presently existing taxiways for GA departures.

2. The upgrading of existing satellite and reliever airports. In many cases the most economically efficient (lowest cost) method for enhancing effective capacity in metropolitan areas may be to ensure that alternative landing sites are readily available for use, particularly in instrument meteorological conditions (IMC). It was observed that current funding policies do not take into consideration the full beneficial effects that would result from the development of reliever airports, with the result that the qualification formulae for Facilities and Equipment funding effectively ignore the status of some airfields as being potential

relievers. To correct this situation it is suggested that the FAA should confer special status on reliever airports, to encourage appropriate instrumentation, lighting, and safety measures for such airports.

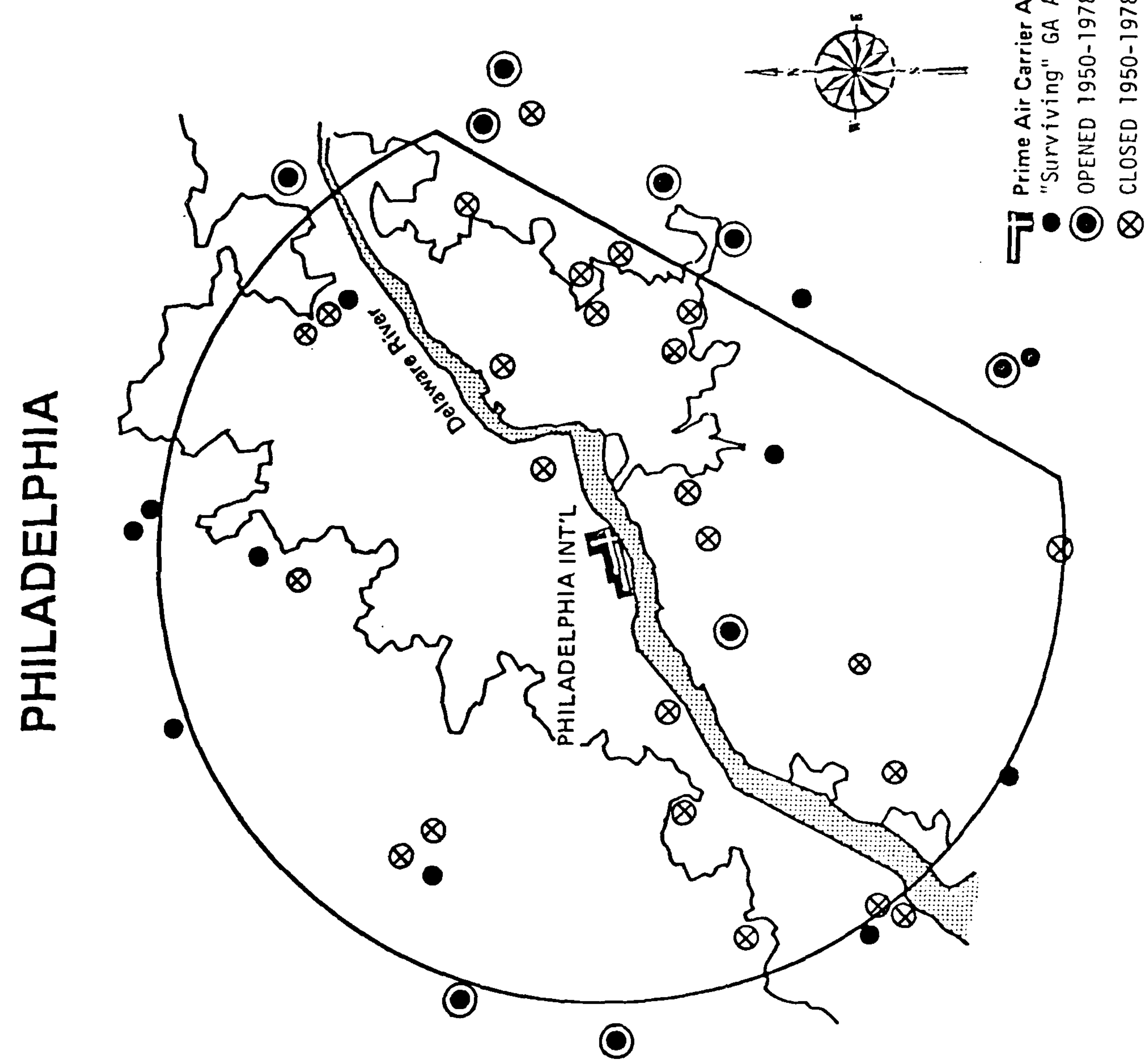
It was also observed that many GA operators have the conviction that the air traffic control system effectively discriminates against IMC movements from some of the smaller airports, contrary to official FAA operations policies. The group asserted that if such discrimination (i.e., in obtaining IFR departure releases) exists, it is counterproductive to the ultimate goal of spreading aircraft movements to less congested airports.

3. The retention of existing small airports and the construction of satellite and reliever airports. Apart from the simple enhancing of the capabilities of relievers or potential relievers, the group expressed particular concern over the trend toward the conversion of many small airports in metropolitan areas to non-airport uses. The trend in the closing of small airports is dramatically illustrated in the Philadelphia metropolitan area. In 1950 that area supported thirty-five general aviation airports (see Figure II-1). Since that time twenty-four of those airports were closed and only nine were opened, for a net reduction of fifteen, or forth-three percent. Moreover, within the central portion of the area the number of general aviation airports suffered an even more precipitous decline, dropping from twenty-five to five, or eighty percent.

The group found that the full advantages to the metropolitan area and/or region of retaining these airports were rarely given due consideration in the planning and political processes. It was observed that the construction of satellite and reliever airports may be the most cost-effective way to increase effective capacity for a congested metropolitan hub. Equally

FIGURE II-1

COMPARISON OF PUBLIC-USE AIRPORTS IN THE PHILADELPHIA AREA
1950 v. 1978



important, the preservation and enhancement of the capabilities of existing reliever airports could mitigate growing congestion at the busy principal airport in a metropolitan region, thereby benefitting all who use that busy airport and all who might otherwise be compelled to pay for its expansion or relocation. Although the benefits in either case are widespread, diffuse, and not directly apparent, often a great portion of the direct and indirect costs are concentrated on the host community within the broad metropolitan area. While ADAP and other federal financing assistance may largely absorb the out-of-pocket costs to a community for the construction and operation of the airport, real monetary costs in terms of property taxes foregone (as the land occupied by the airport is often prime industrial or commercial real estate) and other perceived costs to the community, such as noise, perceived safety hazards, and other environmental concerns receive considerable attention in such a community whenever a policy option regarding the airport appears. The group argued that total, overall benefits of retaining reliever, satellite airports and the construction of new satellite or reliever airports should be weighed against total costs; to do this effectively would require a stronger emphasis on regional airport system implementation of regional plans as a prerequisite for funding.

4. The reassessment of military requirements. The patterns of use of existing airports are to some degree influenced by Department of Defense policies regarding civil use of military airports. Following an analysis of those policies group five has reached the conclusion that civil requirements for airport capacity should be afforded greater consideration than presently given in determining the joint use of active military airfields in metropolitan areas. The group also expressed the desire to see that the conversion of deactivated military fields to civilian use is further encouraged, and that present military use of civil airports be reas-

sessed, particularly at busy airports, in light of the projected trends in civil aircraft movements.

5. Weighing the costs and benefits of environmental policies. Currently the feasible capacity of many airports is constrained by environmental, particularly noise, restrictions. It is the conclusion of the group that in many instances the scale is unduly biased toward accommodation of these legitimate concerns. Hence, the group has expressed a desire to see that the relevant environmental policies be reevaluated, affording proper consideration to their direct and indirect costs as well as to their benefits. The general public good of "quietness" cannot be viewed as an absolute. Just as we are learning that "clean" air, water, and other environmental elements may be desiderata, the benefits of policies designed to attain environmental purity must be weighed against their real, measurable, and often conflicting public costs, such as increases in traffic delays, energy use, and diminished air travel and commerce. In particular the group has found that the application of arbitrary restrictions on the number of movements, time of movements, aircraft types, and so forth may be particularly ineffective and inefficient in addressing environmental problems, as they assume a static technology (i.e., advances in aircraft noise reduction are ignored). Hence, where environmental standards are appropriate, it is suggested that recourse to "performance-oriented" standards be fully explored. Further, when airport capacity (as constrained by environmental standards) is saturated, the method of adding capacity with the lowest total social cost may involve relaxing these restraints.[1] Practical techniques for equitably adding to capacity in this fashion (such as the purchase of "noise rights", or providing tax abatements to affected property owners and residents) should be developed and tested.

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[1]For example, the designed IFR capacity at San Francisco International is not obtained in actual operation because of noise restraints which preclude or limit the use of some runways under certain weather conditions.

III. Policies to Modify Patterns of Demand for Airport Movements

The crux of the proposition that non- or low-capital policies can increase the effective capacity of the airport system centers on the issue of attempting to influence the pattern of airport use by administrative or economic means. As noted in the introduction to this report, several studies of the capability of the airport/airway system to accommodate the anticipated growth in demand have shown demand patterns to be highly significant. One illustration of how "demand smoothing" may enhance effective capacity is the recent FAA study conducted by Fromme and Rodgers.[1] This study analyzed the increase in effective capacity (defined as the annual throughput for a given average level of delays) which might be anticipated from the adoption of a) a set of technological changes in air traffic control systems and b) "demand smoothing" policies. The technological changes in air traffic control were defined as the "upgraded third generation" (consisting of WVAS, DABS, and ATARS) system. The "demand smoothing" policies considered were hourly quotas and/or peak load pricing.

Individual application of the two policy options demonstrated that effective capacity in a simulated 25-airport network might be more readily increased by the adoption of "demand smoothing" policies than by the implementation of the UG3RD.[2] (Alternatively, at a given level of demand,

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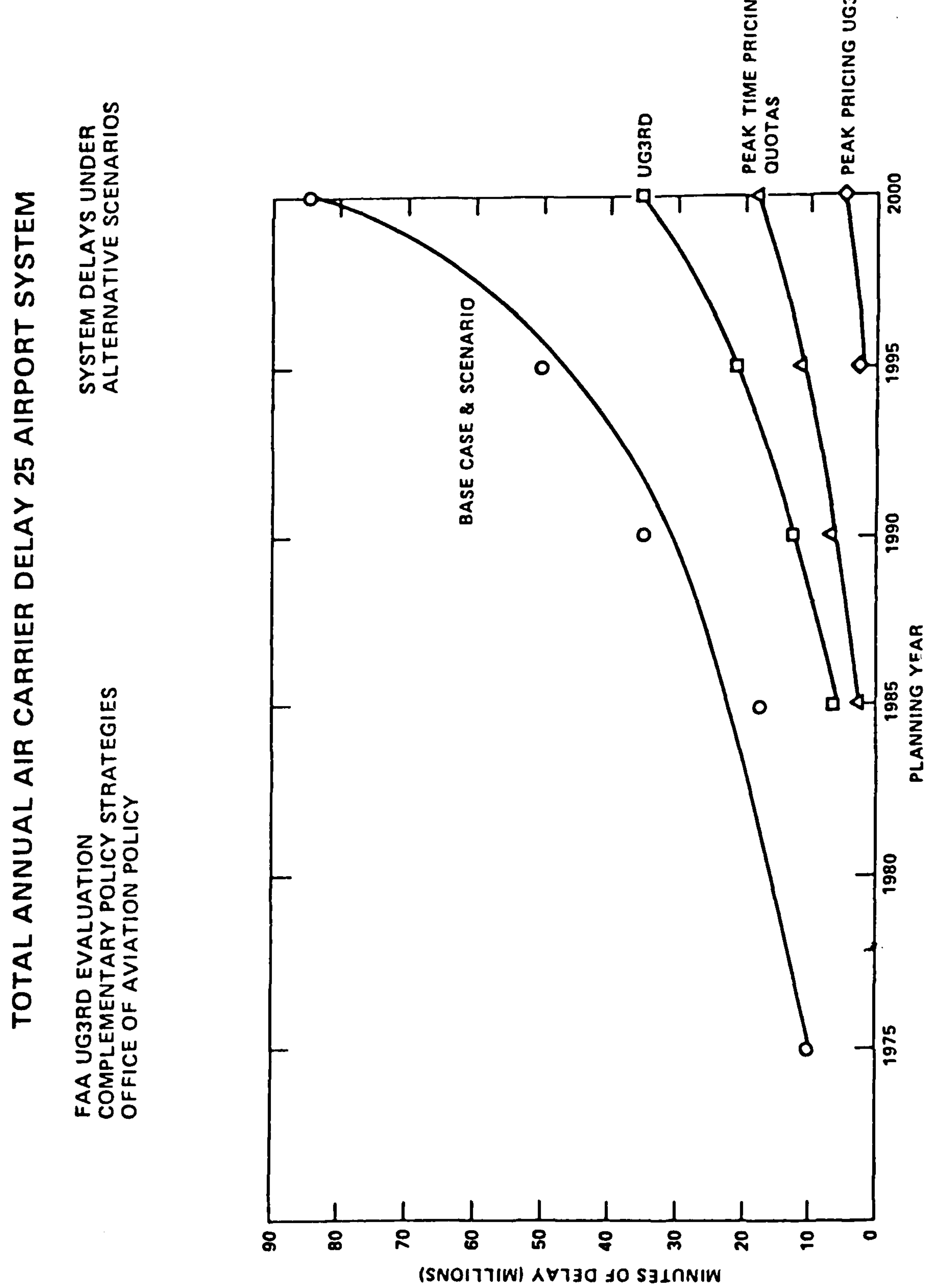
[1] William R. Fromme and John M. Rodgers, Policy Analysis of the Up-Graded Third Generation Air Traffic Control System (FAA-AVP-77-3, January 1977). An analysis of this complexity does involve by necessity many assumptions and inexact simulation techniques, and group five participants did not subject this study to a substantive critique. We employ these results not implying an endorsement of the study or its conclusions, but simply as an illustration of some typical analytical results that should not be ignored.

[2] Fromme and Rodgers, pp. 69, 73. See Figure III-1 and Table III-1.

FIGURE III-1*



*Source: Fromme and Rodgers, Figure 4.3, p. 69.

TABLE III-1*

DISCOUNTED COST OF AIR CARRIER DELAY IN THE 25 AIRPORT SYSTEM THROUGH THE YEAR 2000

FAA UG3RD EVALUATION
COMPLEMENTARY POLICY STRATEGIES
OFFICE OF AVIATION POLICY

SCENARIO	DELAY COSTS[1/] ($ MILLIONS)
BASE CASE	$7107
PEAK PRICING AND QUOTAS	2489
UG3RD	3540
PEAK PRICING & UG3RD	1504

[1/] AIRCRAFT AND PASSENGER DELAY DISCOUNTED AT 10% TO 1975 DOLLARS

*Source: Fromme and Rodgers, Table 4.4, p. 73

aggregate delays were forecast to be reduced to a greater extent by application of demand smoothing policies than by application of UG3RD.)

The issue of demand restraint at congested airports is not a new one; the debate has waxed and waned over the past ten or so years. Moreover, there is no indication that the issue will become moot, unless the projected increases in aircraft movements discussed in the introduction prove to be erroneous. Therefore, group five spent the majority of its meetings in careful examination of possible policy options to modify demand patterns at congested airports.

There have been many techniques suggested for smoothing and/or restraining demand at congested airports, and the number of possible variations of these techniques appears to be almost limitless. In order to facilitate an orderly and comprehensive appraisal of these policies, the group found it convenient to divide them into three basic policy approaches:

The first category considered was the "hands off" approach. Basically, this policy requires that airport use be accommodated on a "first come, first served" basis. This policy prevails at all but a few airports today. In practical terms the policy implies that congested airports are expected to operate with significant delays, available capacity being rationed to those willing and able to pay the costs of delay.

The second category considered was the "quota" approach. By use of this policy the number of movements consistent with an airport's capacity is apportioned among its users. Quota restraints are currently in use at four airports in this country.

The third category considered was the "pricing" approach. This approach specifies that the use of an airport is adjusted to its physical capacity by placing variable prices on its use, such that "peaks" are leveled and "troughs" are filled. Although there are a number of alternative pricing methods by which demand may be equated to supply, most methods involve higher prices in peak demand hours than in off-peak hours; the revenue generated by these peak load pricing methods may or may not bear any fixed relationship with airport operating costs.

The group discussed at great length these three basic approaches from the perspective of the policies' feasibility, effectiveness and fairness.

The consensus of the group was that the basic policy concerning airport use should be to allow all qualified users free access on a "first come, first served" basis, with user fees being designed and administered by the airport sponsor/operator on a cost recovery basis. In those instances where significant excess demand for the airport's use would cause intolerable delays, a quota system similar to those currently in effect should be used. While a majority of the members of group five felt this policy approach was appropriate, representatives of some general aviation users felt that no restraints to qualified users should be employed at all.

Similarly, there was a strong consensus that any use of user fees as a price rationing mechanism to affect airport use would be undesirable. Strong exceptions to the "pricing approach" were expressed, centering principally on its legal and institutional feasibility (e.g., the assignment of management responsibility), and on its fairness. It is quite apparent that should such a policy approach be attempted in the absence of clarifying enabling legislation by Congress, that legal challenges

would ensue. More importantly, pricing approaches, by changing tne pattern of airport usage, would be unfair in the view of the majority of the members of group five. Whether by discouraging use of busy airports at peak hours by carriers serving short-haul, low density markets or by air taxis or by general aviation users, pricing approaches would impose the burden of inadequate capacity differentially and unfairly on the users.

APPENDIX A

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NEW ENGINEERING & DEVELOPMENT INITIATIVES --
POLICY AND TECHNOLOGY CHOICES

INDIVIDUAL COMMENTS AND STATEMENTS

Chapter IV - Topic Group 4

"Individual Comments and Statements"

Minority Opinion to Chapter 4, Section 3.6

Airline Pilots Association (ALPA) Position on

AIRBORNE COLLISION AVOIDANCE SYSTEMS

These systems--of which there are several forms--are considered by the FAA to be in competition with the ground-based DABS/ATARS system. The FAA is in the position of evaluating CAS competitors. One is its own system, the DABS/ATARS with an active BCAS as the backup in areas not covered by DABS, and others thrust on it by the aviation community are the trimodal BCAS and the ACAS which has received renewed interest. This conflict, we believe, accounts for the delay in development of an airborne collision avoidance system.

ACAS

During the Senate hearings in late 1971 and early 1972, the FAA was told to evaluate ACAS systems proposed by three companies and report back. The FAA rejected (ALPA concurred) all three because new equipment would be required in all types of aircraft. As originally proposed, ACAS could provide vertical-only maneuvers, would have an unacceptable false alarm rate due to range-only information and would have a command-only display. ALPA would not object to this system if these limitations are eliminated and if the ACAS can meet the criteria that we have established.

Active BCAS

An active BCAS national standard had been published for comment; however, due to its dependence on DABS and the necessity to be turned off in dense airspace, it is not a complete collision avoidance system. Also, the implementation of this system is largely dependent on the successful development and implementation of DABS hardware. This will have a net effect of delaying collision avoidance protection at dense traffic locations until DABS ground equipment is installed and will provide limited effectiveness in remote areas until DABS transponders are installed in participating aircraft. This design does not have a passive mode and must be equipped with a directional antenna for obtaining bearing information. The accuracy obtained with the addition of a directional antenna is not sufficient for reducing false alarms. Without the antenna, this is a range-only system similar to that of ACAS. The system proposed is still one that is capable of vertical-only maneuvers which would result in a command display to the pilot. This produces problems with the present ATC structure and pilots do not want a command-only display. The proposed system is not independent of the ground system and, therefore, would not provide an independent backup system to the present ATC system nor the future DABS system.

Trimodal BCAS

The trimodal design offers several modes of operation, including a passive one in which the device does not transmit but simply listens to other transponders replying to interrogations from the ground in areas of heavy traffic. This design enables BCAS-equipped aircraft to determine and display to the pilot the location of the threat aircraft. Thus, the pilot can determine how to avoid the threatening aircraft without interfering with other traffic, given the proper display, and can do so without necessarily changing altitude. All aircraft presently equipped with ATCRBS transponders would receive protection even without buying a trimodal BCAS. The trimodal BCAS, we understand, has already undergone preliminary testing of its active mode, and the other components could be completed within one year. The system would not be delayed by future implementation of DABS and could be implemented in less time than that proposed by FAA for their "full" capability BCAS. We understand that the complete trimodal system could be implemented in two to three years. This system would utilize present internationally approved standards for transponders and not have to wait for approval of those modified for the DABS format. The cost of this system is estimated at $25,000 as opposed to the estimate of more than $50,000 for FAA's "full" capability BCAS.

FAA "Full" Capability BCAS

The FAA says that a "full" capability BCAS is far in the future and very costly, and that the system is an extremely complex array of avionics equipment. These same objections could be raised concerning ATARS, but the FAA does not mention that problem.

We at ALPA have found it very difficult to determine the FAA's policy and intention regarding BCAS. The effort to develop BCAS needs to be emphasized by proper legislation. If the same determination given to DABS were given to BCAS, we are sure that an acceptable system could be realized in less than three years.

An acceptable collision avoidance system would:

1. Provide air-derived data on the relative position of nearby aircraft suitable for the pilot to use horizontal and/or vertical maneuvers to avoid a collision.

2. If transponders are utilized, be based on the ICAO radar beacon transponder system utilizing the secondary surveillance radar ground and air signals thereby expediting U.S. and worldwide usage at the earliest date and at the lowest cost.

3. Optimize pilot usage of other available onboard sensory inputs and thus provide maximum flexibility to the pilot's decision-making function for collision avoidance.

4. Be capable of providing bearing information and thus reduce the false alarm rates in dense traffic areas to an acceptable level.

5. Operate adaptively in all air traffic densities. Bearing, range, altitude and identity of surrounding aircraft should be available for pilot usage.

6. Be able to provide pilots an independent assessment of the safety and integrity of ATC functions, such as ground radar vectoring, RNAV, VHF-COM, and future systems such as DABS.

7. Be designed as a "stand-alone" system not dependent upon, or waiting for, the international acceptance of DABS. CAS should be designed as an independent pilot monitor of the ground-derived data from DABS and secondary surveillance radar.

8. Be considered as a pilot's means of assuring his separation and control of distance for air-to-air spacing to assist ATC operations and assure compatibility with the present ATC system.

9. Display bearing, range, altitude and identity in a form suited for real-time onboard computational techniques that can provide the pilot instant assessment of nearby traffic, identify any threats within that traffic, and assist the pilot in executing the best avoidance maneuver if one is required.

10. Provide the pilot advisory information for his judgment of possible actions; "Commands" lacking reason or pilot judgment should be avoided.

11. Not create any signal interference by unnecessary air interrogations in medium or high density traffic that could in any way jeopardize the existing use of radar beaconry or interfere with another aircraft's ability to measure the critical parameter of a threat.

12. Provide control of all commands by use of a threat logic and resolution to prevent the domino effect.

13. Provide the pilot a display of traffic information, including the bearing, range, altitude, and identity of other aircraft in his airspace.

14. Control all interrogations by sensing the secondary surveillance radar signal environment to assure no significant risk to the existing ATC system caused by such interrogations.

MINORITY OPINION OF AIR TRANSPORT ASSOCIATION (ATA)

While the Air Transport Association of America endorses the concerns and approach identified in the first and last paragraphs of Section 4.4, the examples given in the second and third paragraphs limit the investigation to certain areas, some of which have already been, or are currently being thoroughly investigated, and other areas which are the responsibility of FAA Flight Standards rather than R&D.

Deletion of the second and third paragraphs of Section 4.4 would eliminate the misleading material and make it acceptable to ATA.

Some efforts which would more directly address the concerns identified in the first paragraph were included in the FAA's Aircrew Performance Enhancement and Error Reduction (APEER) program as follows:

1. "Command and Control During Flight Under Stress": to determine the best role of the captain and other crew members during high workload or stressful operations (including the question of whether the captain should fly the aircraft in these conditions versus emphasis on managing the flight deck).

2. "Assessment of Pilot Reliance on Automatic Warnings": to determine if automatically triggered warnings of hazardous flight or system conditions decrease pilot sensitivity to avoidance of such conditions.

Chapter V - Topic Group 5

"Individual Comments and Statements"

October 25, 1978

COMMENTS: George W. Douglas

Upon reading this report it should not be inferred that the absence of a detailed discussion of the pros and cons of various strategies for dealing with excess demand for airport capacity is indicative that the issues were glossed over in the group's deliberations. On the contrary, the issues surrounding the policy proposals, especially those concerning "pricing solutions," were discussed extensively, but the emotive content of the proposals proved to be so high that it became impossible to present even a format for their detailed appraisal.

The aversion to pricing solutions by the users is understandable. The notion, so easily accepted by market-oriented economists, that prices serve a rationing and allocating role as well as a cost compensating role is neither well understood nor accepted by general society; witness the recent turmoil in Congress concerning attempts to "repeal" the laws of supply and demand in the energy sector. Given the public's reluctance to allow free operation of the market to allocate a distinctively private sector good, it is not surprising that users would be wary of installing price as a market allocation mechanism for a service produced by the public sector. In this instance the direct users clearly perceive the injurious characteristics of allocative solutions that are based on pricing. General aviation users are aware that they would be substantially "priced out" of many congested "air carrier" airports and that those continuing to use the airport would pay substantially higher fees. The slots thus vacated would apparently accrue to the air carriers, who would also pay substantially higher fees for their use. In economic terms, the scarcity rents that the carriers now accrue by virtue of their assigned slots would

be transferred to the airport operator. Apparently the carriers believe that their losses in scarcity rents would exceed their gains from garnering a larger share of all operations.[1] Further, the carriers individually may perceive that the redistribution among carriers and the consequent redistribution of each air carrier's operations that might occur as effects of a pricing approach would be disadvantageous. To keep the issue in true perspective it should be noted that it is easy to overplay the implications of price allocation as being a matter of air carriers versus general aviation, for only a tiny fraction of general aviation movements are involved. In fact, at many affected airports the current level of general aviation activity is negligible. Such gains in economic efficiency as would evolve from price allocation would principally result from the effect on airline scheduling practices.

As the report proposed by the group refrained from describing the use of pricing for the resolution of excess airport demand, a short sketch of its effects (as commonly perceived by economists) might bring focus to the issues involved. To begin with, the present system of charging time-uniform landing fees varying only with weight makes as much economic sense, as Alfred Kahn would suggest, as "selling every item that comes out of a grocery store at a uniform price per pound, regardless of what it is."[2] Clearly such a pricing mechanism does not reflect the demand for goods or services or the relative costs of providing them.

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[1]A strictly personal surmise not based on any statements of air carrier representatives.

[2]Remarks of Alfred Kahn, Chairman, Civil Aeronautics Board, at the FAA Consultative Planning Conference, entitled: "New Engineering and Development Initiatives -- Policy and Techniques," March 22, 1978, p. 5.

Although nonmarket methods, such as quotas or rationing, can equate supply and demand, economists point out that generally these mechanisms are economically inefficient, for they do not make the best use (i.e., they do not serve to maximize the economic value) of scarce resources. In the operation of a market economy, prices serve a dual role: First, they ration those goods and services among potential users (consumers), allowing each user to appraise for himself the benefits of its use. As each user compares his likely benefit with the price, the process means that only those uses generating the greatest benefits at a given price take place and that the total benefits of that scarce good or service are maximized. Second, since the price must adjust to equate demand (benefits) to supply, the market clearing price serves as a signal reflecting the desirability of additional resources flowing to that activity. As Alfred Kahn has stated,

> The allocation of scarce airport space . . . is an economic problem . . . [that] will never be made intelligently until the users who are responsible for the incurrence of those costs on a marginal basis--additional use by them imposes these additional costs--those users pay the full cost reckoned on a marginal or replacement basis. Such a change of prices would obviously encourage more efficient use of airports at the proper time. It would not only encourage more even spacing out of the utilization of the airport, it would also encourage the development of the technology that would enable [more even spacing].[1]

As applied to the use of scarce airport capacity, the system most commonly proposed would establish a price structure based on the economic concept of opportunity cost. That is, the differences in the price of airport use that might arise consequent to different types of aircraft would

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[1]Remarks of Alfred Kahn, "New Engineering and Development Initiatives -- Policy and Techniques," p. 6.

be given by their relative time demands on the approach/runway system, plus whatever differential in maintenance costs that might be imposed as a result of their relative weights, and so forth. Contrasted with the present system of fees,which is often based on aircraft weight, the difference in landing fees between the smallest and largest aircraft would be expected to converge to a substantial degree; and in most cases congested airports would be expected to generate higher total revenues.

The effect of the expected more uniform, generally higher, fees would be to redistribute the time pattern of airport use. First, the overall level of the fees would change with the time pattern of demands, yielding "peak/off peak" patterns of prices. This would cause some operations to shift from one time period to another, the shifted operations being those of lesser economic value (as perceived by the operator himself). In general, one would expect to observe flights with fewer passengers (general aviation, air taxi, commuter, and small air carrier operations) shifting away from peak demand hours. Similarly, redundant competitive scheduling at peak hours by air carriers flying large equipment would have a lowered financial incentive and might also be affected. It should not be concluded that the sole effect of price allocation would be to shift demand from peak to off peak hours; at highly congested airports even off peak daylight hours are congested, and the effect of clearing excess demand by price would involve the discouragement of some operators from using the airport at <u>any</u> time.

Another important effect of the rationing of scarce capacity by price rather than by nonprice means would be to install the proper economic signals for airline scheduling and routing patterns. In addition

to altering time of day practices, use of a price mechanism would likely affect the ways in which airlines route their traffic. Many carriers have developed network routings for their traffic which involve hub and spoke operations through a major airport. (For example, at any one time over half the passengers at Atlanta and over a third of the passengers at O'Hare go on to connect to other flights.) To be truly economically efficient, network routing practices would have to take account of all of the relevant economic costs to the airline, including the economic costs of using congested hub airports. By charging less than the economic cost of using a congested airport, the system presently encourages (subsidizes) inefficient routing and scheduling practices. Similarly, the carriers' business decisions concerning the use of large versus small aircraft may be biased if the fees for using airports give the "wrong" price signals.

In the cold light of economic analysis, the changes in the usage patterns which would occur are precisely those that render the policy attractive from the perspective of economic efficiency. Unfortunately these same changes are the effects that are viewed as so undesirable by the direct users. This stark dichotomy merits reflection. First, it is clear that in many cases these changes, by disrupting traditional patterns of use and access -- an unwritten contract, if you will -- destroy property rights. Moreover, the right of access to publicly-provided services has a background which is being recognized in a growing number of instances by the courts. (Examples include judicial rulings and statutory provisions regarding freedom of access to information, the elimination of architectural barriers for the

handicapped, and outreach programs to advise minorities about the availability of health, educational, and welfare programs.) However, there also appears to be a potential divergence between the economically efficient allocation and the perceived "equitable" allocation. For example, the operation of a "pure" pricing system would probably cause substantial changes in service from major hubs to small cities, whether by commuter or certificated carrier. Also, in appraising the equity of this effect, it should be noted that some people tend to invoke sympathy for the "small guy" and, in extension, for "small carriers" and "small cities" (but not generally for "small airplanes").

As we have described above, the users' reluctance to embrace price allocation techniques to deal with excess capacity is understandable, yet at some point it would appear that they will be obliged to consider it. First, the winds of change in the airline industry are flowing towards a greater reliance on market mechanisms. One important aspect of "deregulation" is free entry, which is crucial to the public's reliance on competitive market forces to monitor industry performance. Although conceivably the application of the quota system might be possibly consistent with free entry, it would be awkward at best and would more likely impair the needed competitive forces. Second, as the number of congested airports and the number of carriers desiring to serve them grow, the practical problem of administering (or operating within) a quota mechanism will become unduly cumbersome. Hence, eventually any quota mechanism would most likely collapse of its own weight, if indeed the CAB continues to authorize the carriers to participate via the scheduling committees. Finally, the perpetuation of

the quota mechanism at congested airports would not itself mitigate the substantial shortfall of airport capacity faced by general aviation operators in metropolitan terminal areas.

The challenge of fashioning successful changes in any public policy designed to provide a net increase in public benefit is to structure the policy such that those most deeply concerned will recognize that the change is in fact beneficial and that no group will be unduly burdened by the change. Pricing policies to ration excess airport demand have been debated for over ten years, and the magnitude and scope of the prospective general efficiency benefits have been uniformly challenged by the direct users. These users have tended to prefer the quota mechanism with its preservation of perceived property rights, a preference which is perhaps partly reflective of the "better the devil you know than the one you don't know" syndrome. (Recall the fierce opposition of many of the carriers to "deregulation" and compare it to their present perceptions.) If policy makers do attempt to implement pricing mechanisms, realism (and equity) would suggest that specific compensatory treatment be installed to relieve the disproportionate effects on the users. One logical approach would be to couple <u>both</u> the rationing and the signalling roles (as noted above) of price; hence, prices could be used to signal the need for financing capacity augmentation in congested terminal areas. As noted in the report, a legitimate economic case can be made for augmenting reliever capability and capacity in metropolitan areas, a task which could be most efficiently addressed through regional planning and implementation of airport budgeting. It should be noted that the financing needs may extend beyond operating budgets, concrete,

and hardware: transfer payments to host communities to balance out externalities may be required. The concurrent implementation of an efficient demand allocation program (via pricing) might conceivably succeed if coupled with an appropriate supply augmentation program. Moreover, in most instances, such a combination of programs might well be self-financing.

acap

AVIATION CONSUMER ACTION PROJECT
PO BOX 19029 WASHINGTON, DC 20036
TELEPHONE (202) 223-4498

July 13, 1978

Dr. George Douglas
Southwest Econometrics Organization
3445 Executive Center Drive
Austin, TX 78731

Dear George:

I'm sorry to have to drop out of Task Force 5 on Non and Low Capital Policies to Improve Airport Efficiency. ACAP is a very small group and, due to previous commitments and pressing projects, I can't continue to devote the considerable time required to attend meetings and prepare position papers on airport use. The issue, however, is important to all the users of the air transportation system, and I believe you are approaching the complex and controversial problems in a thorough and balanced manner.

Although I am unable at this time to fully respond to your paper on policy alternatives, I would like to express some general views on the issue of airport use. First, I believe that both quotas and peak time pricing can be reasonable methods of allocating scarce airport resources, depending on how they are implemented. In setting appropriate quotas for various classes of airport users, the FAA should take into account the fact that one commercial flight may transport 50 to 100 times as many persons as one general aviation aircraft. Since most of the funds for FAA operations and airport development come from general taxpayers and commercial airline users, we believe the system should give preference to common carriers over private air transportation.

Peak/off-peak pricing appears to have considerable potential for expanding total airport capacity and fairly distributing it between competing users. However, the FAA should fully

test the operation of peak/off-peak fee differentials, perhaps at National Airport, before reaching any broad decision on this policy. In devising any system of time-variable landing fees, ACAP's main concern is that the average fee throughout the day remain the same. By this I mean that off-peak charges should be reduced in proportion to the increase in the peak charges. Certainly there is no justification for increasing the total take of airport authorities from landing charges just because that airport is crowded during peak hours. If the structure is a schedule of higher fees for peak times and lower charges for off-peak hours, we believe such a system might encourage efficient airport use and lower fares for passengers willing to travel at less popular hours.

Thank you for the opportunity to participate in Task Force 5, and I appreciate your interest in our views.

Sincerely yours,

Mimi Cutler

Mimi Cutler
Director

Statement of AOPA on Report of Topic Group 5
With Regard to Airport Quotas

Aviation is a growing and dynamic industry that needs flexibility to properly provide all the advantages that aviation can bring to the public. Imposition of quotas destroys that flexibility and freezes airport use at a level that depends on historic use of the past rather than meeting the needs of the future.

Quotas have no provision for expansion and in effect freeze out any but those who have their "foot in the door" by having a place in existing quotas. This effectively would nullify plans for additional air carriers to serve a location under the new deregulation concept or even when approved by the CAB under the old concept. If the existing carriers at a location refused to give up any of their slots under the quota, there could be no additional service. The same applies to the demand for expanding air taxi or commuter service, which would have no way of meeting the demand.

General aviation shares its quota of slots with the FAA, the Coast Guard and miscellaneous other government flight operations. These, too, have no provision for expansion under a quota system. General aviation, with the greatest growth rate, would be the hardest hit.

In simple terms, the quota system is interference with the free market where everyone who is qualified should be allowed to operate. If delays reach a level that is unacceptable to some operators, they will take steps to change their pattern of flight operations, either to other hours in the case of the carriers, or to going to other airports in the case of general aviation. The carriers also may change their connecting flight patterns, thus avoiding taking thousands of passengers into busy airports for connecting purposes when the passengers really want to go somewhere else.

AOPA is opposed to quotas.

acap

AVIATION CONSUMER ACTION PROJECT
PO BOX 19029 WASHINGTON, DC 20036
TELEPHONE (202) 223-4498

November 15, 1978

Dr. George Douglas
Southwest Econometrics Organization
3445 Executive Center Drive
Austin, TX 78731

Dear George:

Since I participated in the early sessions of this task force, I would like to specifically note my disagreement with some of the conclusions of the report.

Section II. The report notes that Group Five recommends construction of new satellite and reliever airports and additional development of existing ones. ACAP has no objection to such a program as long as the costs are borne primarily by the users of these air taxi/general aviation facilities.

At the present time, general aviation is heavily subsidized. Airport user charges are generally based on weight, so that each general aviation operation pays a substantially lower fee than a comparable air carrier flight. For the right to use the federal airport and airways system, general aviation pays a fuel tax, and passengers and shippers pay an excise tax. In fiscal 1978, the general aviation fuel tax accounted for 5.2% of total contributions to the airport trust fund (excluding interest income), while airline passengers paid in 87.7%. A cost allocation study by the Department of Transportation concludes that general aviation pays only a small percentage of the federal costs attributable to their operations. The report states, "the largest short-fall in tax recovery is from the general aviation sector. Only about 20 percent of the costs assigned to general aviation are being recovered thru user taxes." (U.S.D.O.T. 1973, p.1) The general taxpayer is assessed roughly 80% of the system costs attributable to general aviation.

Dr. George Douglas
November 15, 1978

Unless general aviation pays higher taxes and user fees for airport services, the expansion of GA airports will result in further subsidization of private airplane operations by air carrier passengers and general taxpayers. This would turn accepted public policy upside down, asking taxpayers and persons using public transportation to pay the bill for corporations and pleasure fliers who can afford to buy and maintain private aircraft.

We also disagree with recommendation 5 of this section on weighing the costs and benefits of environmental policies. The Topic Group Five report concludes that in many instances the scale is unduly biased toward accommodating environmental, particularly noise, concerns. In our view, these are important concerns and the development in aviation must be compatible with a quieter and cleaner environment. We believe that aviation can expand without trampling the rights of people on the ground.

Section III. The report declares that the consensus of the Topic Group Five was that all qualified users should have free access to all airports on a "first come, first served" basis. ACAP disagrees with this consensus. We believe that the FAA should encourage experimentation with quota and off-peak pricing systems for congested airports which recognize that one air carrier flight may serve more than 100 times as many persons as one general aviation flight.

On a more general note, I would like to commend you for your patience and fairness in dealing with a highly emotional and politicized issue. However, I do not believe that the Group Five report serves any useful function, since the allocation of scarce airport facilities is not a problem which lends itself to a solution by the vote of a government-sponsored industry committee. Group Five included a fair representation of industries and corporations affected by airport rules and fees. It was not balanced, however, by an equal cross-section of the public which is affected by cost, availability and burdens of the airport system. There were no representatives of environmental groups concerned about aircraft pollution and noise, no taxpayer groups opposing federal aid to favored industries, no one to represent citizens who live near airports, and only one lone consumer voice in the cacophony of general aviation demands that the public provide them with ever expanding runways and airports to land their private craft. The consensus in the report is an agreement among various segments of the industry, and we believe it should be evaluated accordingly.

Sincerely yours,

Mimi Cutler

Mimi Cutler
Director

cc: Lawrence Goldmuntz

January 5, 1979

Dr. George W. Douglas
Southwest Econometrics, Inc.
3445 Executive Center Drive
Suite 227
Austin, Texas 78731

Dear George:

Attached are AOCI's comments on the report of FAA Topic Group Five, to be made a part of the final report as a separate statement.

In Larry Goldmuntz's memo of November 28, 1978, he indicates that topic group chairmen will schedule group meetings during January for final review of of the report. Please let me know your plans in this regard.

Sincerely,

/S/

Barney C. Parrella
Vice President
Economic Affairs

Enclosure

cc: Larry Goldmuntz, Economics & Science Planning
Siegbert B. Poritzky, Office of Systems Engineering, Federal Aviation Administration
Duane Freer, Office of Aviation Planning, Federal Aviation Administration

w/enclosure

mf/

International Headquarters: 1700 K Street, Northwest, Washington, D. C. 20006 Phone: (202) 296-3270 Cable: AOCIHQ

AIRPORT OPERATORS COUNCIL INTERNATIONAL

Separate Statement of the
Airport Operators Council International
on the
Report of Topic Group Five of the
FAA E & D Initiatives

January 5, 1979

Dear Mr. Chairman:

On behalf of the United States members of the Airport Operators Council International, and as a member of Topic Group Five, I commend this separate statement to you and ask that it be made part of the final report of the group. United States members of AOCI enplane over 90% of the domestic and virtually all of the U.S. international passenger traffic, and are the public airports experiencing the traffic congestion which forms the basis for Topic Group Five's investigation.

I should point out that on numerous occasions, both as part of the discussions and through written comments (June 22, 1978 and October 30, 1978), AOCI's views were brought to your attention. Notwithstanding these repeated communications, draft report language has not reflected our concerns, even in passing reference. Accordingly, these strong formal objections, reservations and comments are provided.

It should also be noted that, despite my repeated indication that AOCI's views were those of <u>providers</u> of airport facilities, the draft reports and September 6, 1978, Progress Report continually refer to the conclusions and perspective of the group as those of airport <u>users</u>. The intimations of unanimity which are found in the final report,

while applicable to some sections and concepts, are clearly not applicable to others.

Our greatest concern centers on the statements in the draft report regarding environmental matters. We have repeatedly urged that the entire discussion on page 8 be deleted from the report since it is repleat with unconstructive, misleading and factually faulty assertions about an area of public policy that cannot simply be wish into insignificance. For example, very few airports have noise-related restrictions having any effect on capacity, while the report states that the feasible capacity of "many" airports is thereby constrained. Additionally, restrictions having, arguably, an effect on capacity are not arbitrary and ignorant of technological advances, as posited in the draft report, but rather seek to maximize the use of the most advanced noise reduction technology available (e.g. FAR 36 nighttime restrictions, proposed DCA noise level nighttime restrictions, LAX phased FAR 36 regulations, BOS phased regulation, etc.).

The entire concept of focusing on environmental constraints as <u>the</u> major hurdle in increasing airport and airspace capacity is a misplaced priority, and the manner in which the subject is addressed misdirects emphasis. Full and timely compliance by aircraft operators with federal and local noise regulations can potentially increase capacity. It should be recognized that the airport proprietor is legally liable for claims by noise-impacted citizens. Given the source of the noise (aircraft) and the parties liable for its impact (airports), topic group five is in no position to suggest that great emphasis be placed on relaxing environmental standards

in order to accomplish possible short-term, but not significant, increases in airport capacity. The most direct means of addressing the airport capacity problem is through the provision of new or expanded airport facilities.

A second major area of concern regards the suggestion that regional airport system implementation be a prerequisite for ADAP funding of hub airports. Such a recommendation ignores the jurisdictional and institutional realities of most airport hub areas, where reliever airports are not necessarily owned or operated by the governmental entity that operates the major air carrier airport. It is implicitly unfair, and certainly unproductive, to hold the use of trust fund monies at an air carrier hub airport hostage to the accomplishment of an extremely difficult task of inter-*jurisdictional* integration. While AOCI strongly supports the development of reliever airports, there are jurisdictional realities which preclude the course of action suggested in the report.

No mention is made in the report of the "plateau" phenomenon, where practical total saturation occurs throughout the operational day. In such cases, peak spreading is not even an option. The four slot-controlled airports currently under FAA's high density rule are in this category, and other airports are fast approaching this condition.

AOCI is in substantial agreement with the conclusions expressed in the report regarding policies to modify patterns of demand for airport movements. It is our view, however, that policies of restraint should be addressed only in the context of otherwise unavoidable deficiencies in capacity

relative to demand.

Respectfully submitted,

Barney C. Parrella

Barney C. Parrella
Vice President
Economic Affairs

mf/

ACRONYMS

AERA	Automated En Route ATC
AIM	Airmen's Information Manual
ALWOS	Automated Low-Cost Weather Observation System
ARSR	ATC En Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ASDE	Airport Surface Detection Equipment
ASR	Airport Surveillance Radar
ASRS	Aviation Safety Reporting System
ATARS	Automatic Traffic Advisory and Resolution Service
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATIS	Automatic Terminal Information Service
BCAS	Beacon Collision Avoidance
CAS	Collision Avoidance System
CAT-1	Category 1 (Instrument Landing Systems)
CAT-2	Category 2 (Instrument Landing Systems)
CCZ	Continental Confluence Zone
CDTI	Cockpit Display of Traffic Information
CONUS	Continental United States
CPS	Constrained Position Shifting
CRT	Cathode-ray Tube
C/V	Ceiling/Visibility
CVF	Controlled Visual Flight
DABS	Discrete Address Beacon System
DME	Distance Measuring Equipment
DOD	Department of Defense
E&D	Engineering and Development
EFAS	En Route Flight Advisory Service

EFR	Electronic Flight Rules
FAA	Federal Aviation Administration
FAME	Final Approach Monitoring Equipment
FAR	Federal Aviation Regulation
FL	Flight Level
FSS	Flight Service Station
GPS	Ground Positioning System
IFR	Instrument Flight Rules
ILA	Instrument Landing Aid
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
MAPS	Minimum Altitude Performance Specification
MLS	Microwave Landing System
MNPS	Minimum Navigation Performance Specifications
MOPS	Minimal Operational Performance Specifications
MR	Milliradian
M&S	Metering and Spacing
MSAW	Minimum Safe Altitude Warning
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAVSTAR	A satellite navigation system now called GPS
NEF	Noise Exposure Forecast
NMI	Nautical Miles
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board
NWS	National Weather Service
PIREPS	Pilot Reports (of weather)
RNAV	Area Navigation

4D RNAV	Four Dimensional (Space and Time) Area Navigation
SAFI	Semi-Automatic Flight Inspection
SIDS	Standard Instrument Departures
STARS	Standard Arrival Routes
TCA	Terminal Control Areas
TERPS	Terminal Procedures
TRACON	Terminal Radar Approach Control
TRSA	Terminal Radar Service Area
TSC	Transportation System Center
VAS	Vortex Advisory System
VASI	Visual Approach Slope Indicators
VFR	Visual Flight Rules
VHF	Very High Frequency
VLF	Very Low Frequency
VMC	Visual Meteorological Conditions
VOR	Very High Frequency Omni-Range
WVAS	Wake Vortex Avoidance System

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